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PRESIDENT'S MESSAGE

D. G. Malcolm

Some Thoughts on the Installation Phase of Industrial Engineering

First, let me ask you how you have progressed in the ONE for ONE Plan. Have you done your share? If not, why not get started TODAY?

A colleague of mine, whom I respect very much for his powers of discernment and knowledge of successful business practice, made an observation to me the other day that started me thinking. His story revolves around one of those coincidences that we all occasionally experience. Recently he had been reading the literature of some thirty years ago wherein an Industrial Engineer for Pacific Reduction Company[1] reported his experiences in introducing change into his company. This author related the need for "selling" the foremen, supervisors and workers in the new methods or processes which the Industrial Engineers had designed and which, if accepted, would provide an adequate economic payoff to the company. The difficulties of this most important step were delineated and the need for patience and perseverance was stressed.

Now the coincidence. My colleague then mentioned that only a few days later he happened to be talking with Industrial Engineers working now for Pacific Reduction Company, and that it was quite obvious that the *same* stress on "selling" was still the major theme in the Industrial Engineers' approach. He then made the observation that is the theme of this message and which, I believe, is food for serious thought. He said that from this experience one might make some argument for the point that Industrial Engineers seemed to spend a lot of time on methods of solution that continually needed to be supported with a lot of convincing argument before they were accepted. One might well feel, he said, that in thirty years a satisfactory approach to such problems would have been effected and that the job of

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[1] I hope there is no real company by this name. If so, it is another coincidence.

(Continued on Page 20)

THE NEW LOOK IN INDUSTRIAL ENGINEERING

By M. E. SALVESON[*]

The measure of a man is in the problems that surround him.—A. Lincoln.

Ours is a relatively mature profession; we can trace our practice as far back as Babbage and Taylor in the last century. It is surprising, therefore, that it should be undergoing a pervasive and fundamental reorientation. But, the change is impending and we have before us a new challenge to our professional skill and ability. The opporunities it presents in personal and professional advancement are great. Our purpose here is to review and extrapolate these trends into the future; from their course and direction, we then may determine our educational and professional development requirements to meet that challenge.

As an Engineer, I happily observe that the New Look in Industrial Engineering is "Engineering" — but at a more advanced and scientific level than typical heretofore of Industrial Engineering. The New Look results from two sources: 1. more consistently using the "methods and principles of science," and rigorous engineering disciplines to describe and to solve our Industrial Engineering problems, and 2. the growing logical extension of our methods from manufacturing to the business as a whole.

In order to evaluate the New Look, let us first re-examine "Industrial Engineering, the branch" in relation to "Engineering, the tree." Engineering is defined as "the art and science by which the properties of matter and the sources of power in nature are made useful to man in structures, machines, and manufactured products." (Webster) Industrial Engineering then could be characterized by "made *most* useful." If we accept this definition, then the challenge of Industrial Engineering is to use all relevant scientific methods and principles to maximize industrial[1] efficiency. This is indeed a broad challenge, demanding the highest level of engineering proficiency and knowledge.

But what does it mean in concrete day to day terms? How can or will it affect what Industrial Engineers do? To answer this, let us re-cast some of the usual Industrial Engineering functions or assignments into a conventional engineering frame work. We refer, in part, to the functions listed by Professor H. P. Emerson, University of Tennessee, in a paper before the American Society for Engineering Education.

Cost Accounting, Production Control and Quality Control

These functions can be lumped as components of a "management control system" concerned with controlling, respectively, the cost, quantity, and quality of production in relation to some predetermined standard. The notion of these functions as a "system" is not new; but I believe it is new that "engineering" methods of systems analysis should be used for their design. Indeed, under this view, this sytem may be considered a "servo" system, which is amenable to analysis by methods developed already for design and analysis of servo mechanisms. The only feature differentiating these management control systems from servos as usually considered by systems engineers is that the former often may have more "human links." But, having more human links does not negate the value of servo theory in designing these systems. Hence, we now see that properly to design a management control system should require facility in the concepts underlying servo theory, including network and systems analysis, differential and difference equations, LaPlace transform, and information theory, as well as, of course, the usual understanding of the operating requirements which are placed on the managerial control system. In addition, the greater emphasis in the management control system on discrete messages requires familiarity with digital data-handling equipment and components.

Of course, many "practical" Industrial Engineers and managers may question this approach; after all "wasn't my system a success without all that mathematical analysis?" My only answer is, by analogy "yes, you have designed management control systems without these tools just as the Romans designed bridges and aquaducts without any help from modern science. Now, however, crude rule of thumb methods must give way to the methods of engineering and science." Indeed, with the advent of the high speed computer and data processing equipment in industry, it becomes virtually a necessity to think in these terms in order most efficiently to design the modern management control system. As we include these high-speed high capacity elements into our system, we now are obliged to consider how they interact dynamically with other components in a real-time control system. The usual technique for this problem is, of course, frequency analysis. This requires that we consider the computer, operator, and satellite equipment together with the computer program as a filter which is represented by a weighting function (or a transfer function) in the mathematical model of the system. Given this approach it becomes possible — through further analysis suggested below — optimally to select the weighting function in relation to the characteristics of the remainder of the total system and the behaviour response desired or considered optimal. Indeed, one already has real problems now in deciding in a highly automated management system many practical matters such as frequency of reporting, detail of reporting, when to take corrective action as a function of degree of perturbation from standard, etc. The engineering approach to systems problems of this type already well developed by electrical engineers now will become increasingly necessary to the design of our management control systems. The competitive advantages of such system to the firm using it will, in the long run, be the best argument for those methods of analysis.

Inventory Policy, Investment Policy (Engineering Economy), Cost Estimating and Bidding, Inspection Policy

Let us aggregate these under the general term "management decision procedures." The decision procedures may be viewed as describing the operation of the specific elements within the servo system which actively control the production system. From this view, we wish to design a decision procedure such that, in the long run, the resulting decisions will tend to be optimal. Although the exact procedures for each of these decision functions will vary somewhat, the underlying theory and method are the same. For these we require considerable facility in probability theory, statistical decision functions, convex sets and functions, and calculus. Related to these, we need new insight into "loss functions" for such factors as "out-of-stock" penalties, "failure cost," etc. When properly integrated into a mathematical model of the system, we then have the basis for designing optimal decision procedures. See for example (1).

Time-Series Analysis

One area seldom studied by the Industrial Engineer is sales analysis and forecasting. In order properly to handle the design of a management control system and decision procedure, it is necessary to have information on the market behavior of the firm's product not now ordinarily provided by market research departments. Hence, it may become necessary for the Industrial Engineer to obtain the information himself. This brings him vis-a-vis a new set of problems, such as autoregressive analysis of time-series (sales and inventories); smoothing and extrapolating time series; statistical inference in dynamic economic models. In relation to the economic models, he will need information on availability and reliability of revelant economic time-series data (GNP, etc.), regression coefficients for any series that may "lead" his product sales, lead information as may be obtained from Inter-industry Leontief models, and methods of estimating or predicting trends in business cycles.

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[*] Prepared while under contract Logistics Branch, Office of Naval Research; and while at the Management Sciences Research Project, University of California, Los Angeles. This paper is a very slight revision and combination of a paper presented at the Fifth Industrial Engineering Institute, University of California, 1954 and a paper read at the First Industrial Engineering and Management Seminar, University of California, Los Angeles, 1953.

[1] Note: "Industry" is not synonomous with "manufacturing," but rather with "business." Hence, industrial efficiency is not manufacturing efficiency, but business efficiency. The latter, of course, is measured by net profits or net social utlity.

From all of this, he can distill a stochastically-defined time-demand function for his firm's products. This will mean, of course, a probilistic sales forecast which then can be used with the statistical decision procedures.

Programming

A familiar area to the Industrial Engineer, but perhaps involving here some unfamiliar concepts, is the general problem of work loading and scheduling over time. In order to perform these functions analytically, it is necessary to compile mathematical models of the structure of the manufacturing system. Depending upon the nature of the system and the intended use of the model, the model may be linear or nonlinear, discrete or continuous, dynamic or equilibrium, stochastic or deterministic. Then, according to the nature of the model our mathematical techniques for optimal solution (optimal loading and scheduling) may be drawn from linear algebra and matrix theory, particularly in relation to inequalities, calculus of variations, (fixed end point or bounded optimization problems), game theory, combinatorial analysis, monte carlo search methods, or other.

Of course, in order to construct the model, it is necessary to have the usual familiarity with engineering processes and equipment, time study and work measurement, learning and fatigue, etc. But again, for refined, efficient programming methods, it is necessary to define these processes, work standards, etc., stochastically rather than with a single parameter system as is now general practice.

At this point the reader may ask, "what would I do with all this mathematics—statistical paraphernalia about the business?" The answer is that the Industrial Engineer then truly can become "management's engineer." He has, through the foregoing, constructed a model or series of models of his firm's business. Now, by a prior manipulation of the model in relation to any planned decisions, policies, or procedures he can advise management *in quantitative terms* of the probable outcome or range of outcomes they will produce as well as of the optimum or most profitable decision or policy. He thus provides scientific, quantitative bases for business plans, policies, decisions.

In a sense, this engineering function is similar to the original concept of the controller as a top level business analyst and adviser to management on relative merits of alternative business plans and proposals. However, the controller's primary tools have been only accounting methods of analysis and his mature judgment. From the foregoing discussion, it is clear that these often are not fully adequate for the analysis of the very intricate, complex relationships among the many factors affecting the operation and profitability of a business and for computing or determining optimal courses of action. The Industrial Engineer with his increasing facility in use of powerful scientific methods of analysis and his broad understanding of industrial and business processes is becoming a primary adviser to top management on policies and courses of action affecting the profitability of the business.

The "New Look" that makes the Industrial Engineer "management's engineer" also creates an organizational problem. Heretofore, Industrial Engineering usually has been part of the manufacturing organization. Now, however, the range of investigation, analysis and recommendation may cover the entirety of the business, since the studies are in relation to the profitability of the *business as a whole*. Hence, the Industrial Engineering Department in the future will increasingly report to the chief executive of the business, just as the controller now does.

Whether or not this newly evolving Industrial Engineering function can be effectively combined with the controllership function is still to be determined. Since it performs one of the functions originally envisioned for the controller, it might be logical to combine the two because both report to top management and would be concerned with analysis of behavior of the business. The largest obstacles to combining them appear to be: 1. the fundamental differences in the disciplines of the scientist or engineer on the one hand and of the accountant on the other, and 2. the unenlightened accountant's preoccupation with historical data and analysis, 3. the rigidity of the accounting rituals which are legally enforced upon the accounting profession, and 4. some problems, such as design of the organizational structure, etc., are outside the purview as usually conceived for the controller.

From an educational point of view, there is still another set of problems to be reconciled. Should the training for this field be in the engineering college, but with a strong management and economics orientation or should it be in a school of business administration with a strong science, mathematics, and basic engineering curriculum? It has been observed that many engineering graduates in this field lack an awareness of the firm as an entity whose behavior is subject to economic laws; their economics training often is restricted to Engineering Economy — a set of techniques of little value in the above discussed system. Also, their concept of management functions is weak. On the other hand, Business Administration graduates often have a profound lack of facility in mathemathics and numerical manipulation. They often are unable to construct the necessary abstract mathematical-statistical models or think in abstract terms. It appears an especially-designed unified curriculum spanning economics, business administration and engineering subjects with emphasis on the management and social sciences instead of physical sciences may be necessary in order to prepare best for this new field. Indeed, of all branches of engineering, the Industrial Engineer more than any other must be a "scientific or engineering generalist."

The impact of this enlarged concept of Industrial Engineering also will be felt in the choice of careers. Presently there is a very strong tendency for Industrial Engineers to progress up and out of engineering and into managerial or administrative positions. This is due, often, to the fact that the present top Industrial Engineering positions are below the abilities of the more able engineers. Under the logically developing scheme, we will find that Industrial Engineering is a broader, deeper profession, retaining challenges for the entire career of the most able engineers. It should be noted particularly that "broader, and deeper" mean time study and quality control, which now are so often over-emphasized, will revert back to their proper perspective as Industrial Engineering becomes also a top management adviser and analyst on the structure of broader more basic business problems. In this role, there will be virtually unlimited challenge and opportunity for the engineer interested in the study and analysis of management. It will become less frequent and less necessary for the outstanding engineer to become a manager in order to continue his growth and development. As management's engineer, his field is unlimited.

Aside from the increased professional challenge from the broadened scope of Industrial Engineering there appears to be also a growing competitive challenge from an unexpected direction. Some of our colleagues from the other sciences have banded together under the name "Operations Research" and are promoting that name as representing modern "quantitative methods in management," "science of decision," "simultaneously industrial engineering, statistics, quality control, market analysis, applied mathematics, applied physics, applied psychology, and Econometrics," etc. (See 4.)[2] Upon close examination, it becomes impossible to me, at least, to distinguish between the proper concept of Industrial Engineering as we have been discussing it here and Operations Research as they propose and define it. However, their concept of Industrial Engineering is not at all flattering, as related by a recent incident in a conference on Operations Research at which I presented a paper earlier this year. In response to a question from a conferee, one of the host speakers gave this answer as to the difference between Operations Research and Industrial Engineering. "The difference

(Continued on Page 21)

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[2] Should this article be read by any of my friends who call their work operations research, I hope they will consider this an exhortation to IE's to improve their practice and to IE Departments and BA Departments to improve their curricula. It is not intended as a criticism of their excellent work.

Industrial Engineering, The Media Of Management Control

By GEORGE A. JAGGERS

President, Monarch Manufacturing Company, Fort Worth, Texas

Based on an address before the Dallas-Fort Worth Chapter of AIIE, February 3, 1954

We will discuss the Industrial Engineer, first as a professional man and review some of the measures which should be taken by him to provide his clients with a better understanding as to his profession, functions and ethics. Following this, we will discuss the Industrial Engineer as a salaried employee and endeavor to establish a practical working relationship between top management and points of manufacturing conversion through the Industrial Engineer. In addition, we will approach the subject from the viewpoint of management and discuss means by which management may enjoy improved planning and tighter control over operations, and then I will endeavor to give you some examples of how modern management has successfully used an Industrial Engineering staff as a means of control in depth, and how from that staff frequently comes the material which is eventually developed into personnel to perpetuate management.

The title Industrial Engineer has not been successfully established as a professional title accepted by prospective clients. In fact, the Industrial Engineer has but recently established an association which promises to further his objectives in the professional field. Prior to 1910 problems of Industrial Engineering were discussed only in The American Society of Mechanical Engineers. It was before that society that the papers of Taylor, Gilbreth and Gantt were read. In 1910, several members of the Mechanical Engineering Society began to meet separately for the discussion of management problems. The group included Gilbreth, Barth, Cooke and Hathaway. In 1912, out of this society, the Society to Promote the Science of Management was formally organized. The membership of the society increased to more than a hundred by 1917. During World War I, the name was changed to the Taylor Society, and in 1936 the Taylor Society amalgamated with the Society for Industrial Engineers to form the Society for the Advancement of Management. This group flourished and still meets regularly to review detailed problems in management. And finally, as recently as 1948 your organization, the American Institute of Industrial Engineers was founded.

Now that we have the American Institute of Industrial Engineers, it is apropos to explore the meaning of the term Industrial Engineer. The science of Industrial Engineering, born of the present industrial era and currently in the process of evolution, remains to be properly defined. The Dictionary of Occupational Titles defines an industrial engineer as follows:

> A classification title for engineers who supervise production departments of manufacturing plants, lay out machinery and apparatus and determine flow of work for most efficient production, conduct and interpret time-and-motion studies, devise means and set up programs to curb industrial accidents and fires, set up personnel policies and procedures and evaluate jobs and devise and install accounting and inventory-control systems. The definition adds: May specialize in such fields as setting up production cost records and control systems, developing jigs and fixtures, training production personnel, and wage administration. The definition further adds: The following jobs are typical of those classified under this title: efficiency engineer, factory lay-out-man, methods engineer, production engineer II, safety engineer, time-study engineer, management engineer.

This list of subtitles, all directly or indirectly related to the Industrial Engineering field, is at best, confusing. The description more nearly describes a Jack-of-all trades, encompassing everything from fire control to efficiency in top management. Obviously it would be difficult for executives responsible for organization planning to properly catalog the Industrial Engineer and the specific services offered to management of enterprise. I strongly feel that now is the time to establish a common denominator for all the titles associated with the profession of Industrial Engineering. And then let there be established a logical relationship between the various branches of the profession wherein one can readily recognize which branch is best qualified to undertake the solution of a specific management problem.

This relationship may be in the form of a rating which is authorized through the AIIE and is based upon the qualifications and experience within a specific branch of the profession. It then would follow that having qualified in additional branches, the rating would ascend on a basis which would identify those branches in which the individual had acquired proficiency. Although such a rating may be violated by the eager and impetuous, once such standards are placed in the hands of management, management can readily determine the proper classification for the individual engineer.

Industrial Engineers claim proficiency in job evaluation. I therefore cannot believe that the profession as a whole cannot devise a means of evaluating the qualifications and experience of its own members.

For those who would protest for the reason that such a plan may detract from their own conceived position in the profession, let them have the vision and objective interest to protect their future standing which they will have developed through years of practice and experience.

In addition, there needs to be promulgated a clear description of how the Industrial Engineer functions. This description should apply to all members of the profession, regardless of the particular branch in which they have been qualified. Although I do not presume to be qualified to prepare the description which will fully satisfy this need, I believe that the Industrial Engineer's principal functions are threefold, and I offer for your consideration a brief, simple description of these three functions.

First, the competent Industrial Engineer is an analyst. He is trained and disciplined in the objective study of known or projected situations for the purpose of properly identifying the various factors which may be involved, and to separate the constituent elements in each factor so that they may be considered separately, or in relation to the whole.

Secondly, he is a planner. The facts, ascertained through analysis and properly assembled, tend to point the way for proper planning to attain a desired result. The analyst, therefore, is the first to visualize the plan necessary for corrective measures, or the plan most likely to assure success of a given project.

And thirdly, he is a controller in the sense that he well knows that any plan must incorporate features of comparison and verification to measure progress and results, and he is well informed as to the most efficient methods which may be employed.

These terms—analyst, planner, controller—are familiar to top management, and indicate to them a pattern of work to be performed for which they recognize a need. Likewise, the terms are understandable to the small business man who might be interested in engaging the services of an Industrial Engineer, if there were a clear understanding of the services to be rendered.

Your institute, the AIIE, while young, has before it the opportunity to establish itself for all time as the one accepted society for engineers in all phases of Industrial Engineering who are willing to accept high standards of proficiency and ethics.

In fact, the professional engineering firms such as Booz, Allen & Hamilton, McKinsey and Company, and others, have well recognized the need for properly evaluating the capabilities of engineers, and the need for clearly defining engineering procedures. One of the principal services which they render clients is the selection of the right man for each assignment, and the providing of a clear definition of orderly procedures to be followed in fulfilling such assignment. The professional management engineering firms organized the Association of Consulting Management Engineers and published a brochure for management which, among many other things, outlines the services to be rendered. For those not familiar with this publication, I quote from the heading, "What Services Are Rendered?"

> The first step in service to a client is usually to make a complete analysis of the problems and to render a report, though circumstances often require immediate service on known problems.
>
> This analysis may be a survey of the entire business, or of a particular situation. Such surveys are exhaustive and objective, and are exacting in their demands on professional capacities.
>
> The second step in service to a client is the development of a constructive program arising out of the survey and report, using the staff of the engineering firm to the extent necessary to direct and supplement the client's organization.
>
> This may involve steps as extensive as planning a business and its product, constructing its plant, or operating a business during an initial or critical period.
>
> Or the consultant may work out a program of improvements, using the client's own personnel, or may train the client's personnel to carry it through.

In addition, the Association of Consulting Management Engineers has adopted a brief but adequate code of ethics which has resulted in the elimination from the profession of those promoters and profiteers who would exploit the sincere efforts of management to obtain assistance from competent engineers. The first two items in this code of ethics are of primary interest to us here this evening and I quote from this code.

> (1) In serving clients, we shall undertake only that which we are actually able to accomplish, treat as confidential all information regarding a client's business, assign no one to a client's work who is not thoroughly fitted to give effective service on the problems involved, always maintain an unbiased attitude, make every effort to acquaint a client's employees with the principles applied so that suggested improvements may be understandingly administered by them, and always consider the best and most lasting benefits to a client's business as a whole.
>
> (2) In making a presentation of our experience, reputation, and ability, we shall rely entirely upon dignified and truthful statements. We shall not attempt to serve our clients by any means other than those consistent with the highest professional standards.

The Association of Consulting Managment Engineers is an association of firms—not individuals. It is the AIIE which can fill long standing need for the individual Industrial Engineer. I believe there is a distinguishable difference between the Industrial Engineer and the management engineer. The Industrial Engineer should specialize in that area of management having to do with the design and manufacture of product. This would encompass all of the ramifications both directly and indirectly associated with the production of product of standard quality and cost; whereas the management engineer should specialize in that area of management involving sales, marketing, finance, policies, organization, and problems in reorganization and mergers. Neither of these definitions suggests imposed limitations, but represent logical deductions I have made as a result of having been associated with both branches of the profession.

The growth and expansion of American industry has combined to make the most exacting demands on the entire profession of management, and those who would serve management in a professional capacity would do well to recognize that two distinct but related fields are developing for the professional engineer. Those who continue to practice in all areas will soon be authorities in none, for we may be assured that we are yet young in technological development and that the future will multiply management problems manifold.

If the AIIE should share my viewpoint in this matter, it would do well to adopt policies which would identify the Industrial Engineer with his respective field.

The quotations from the Association of Consulting Management Engineers are not made with the suggestion that they be adopted by the AIIE, but I do believe that some positive action as recommended here should be taken to establish equal benefits for the profession of Industrial Engineering.

Let us now turn to the position of the Industrial Engineer as a salaried employee. Perhaps this may best be considered by first defining a management problem and then identifying the function of Industrial Engineering with that problem.

The problem is to establish a means whereby the thinking and planning of top management may be converted into a controlled and positive plan of action. This is especially difficult in planning the manufacturing operations. Early in my career, I recognized this problem to be of critical importance to top management and noted at that time that limited progress had been made in this field. The solution to the problem is the production of manufactured goods on a planned and controlled basis in a definite and positive manner. With this accomplished, we have a plan for manufacturing which becomes part of management's master plan for the over-all project of engineering, sales, manufacturing and finance.

Although it may be debated as to whether any one of these phases is more important than the other, it is generally accepted that the plan for manufacturing must be successfully predicted and executed, or the other phases of the enterprise will never enjoy an opportunity to operate successfully. At least we believe that planning for manufacturing is the most complex, and has a much larger ratio of intangible ramifications. By intangible ramifications in manufacturing, we refer to organization, morale, working conditions and industrial relations which include the entire area recently described as "humanics." With these various intangible ramifications to be considered in the manufacturing plan, it is of major import that the tangible factors which may be determined accurately through applied technology should be resolved with a very minimum of error. The tangible factors are the determination of the proper machinery and/or equipment, the design and construction of the necessary tools, jigs and fixtures, the determination of methods, the establishment of the rate of production, scheduling and routing, evaluation of the various jobs and the establishment of proper job rates, and finally, the establishment of cost standards, which includes material, labor and manufacturing expense.

Unless all variables in this area are reduced to an absolute minimum, and adequate means are provided to measure progress and status, top management will find it impossible to efficiently measure and control operations. Having made its decisions upon unreliable data, management must trust to chance that the final accounting will be profitable. In an organizational structure where the tangible factors are separated and portions become the responsibility of independent department heads, a wide diversity of opinion will be found as to the most efficient, economical or satisfactory plan to be adopted. Assembly of the data submitted into an over-all plan may not reveal this divergence of opinion on details, and consequently the plan itself will have inherent weaknesses which will be revealed in confusion at the time the plan is executed. Such differences must be resolved before the plan is adopted, and resolving the broad general differences through committees will not suffice. Successful execution will depend upon resolving the detailed technological procedures and methods to be employed, prior to the adoption of the plan. With the multitude of division heads, department heads, engineers, foremen and supervisors found in large organizations, it is practically impossible to obtain unanimous agreement on the solution of the problems to be resolved.

Let us state this major problem in its simple terms. How do you get everyone in accord on the detailed methods to be employed in manufacturing? Singular thought patterns are not to be encouraged, for they are a detriment to progress. It therefore follows that all available thinking must be assembled where it may be correctly analyzed and the detailed processes of a plan developed. This point in the organization may be termed a clearing house or an axis around which all manufacturing activities revolve.

The Industrial Engineer should now recognize his opportunity to provide management with this needed axis, and then proceed to evidence to management he is best qualified to perform this function. Indeed, he might well plan his career with this objective in mind. How can the Industrial Engineer best prepare himself for this important position — and then convince management that he is competent and willing to assume this responsibility?

First, he needs to develop a better understanding of management's viewpoint. Management is primarily concerned with planning with the manufacture of goods to be sold at market at a profit which will provide a satisfactory return to the investing stockholders. The sales, costs and profits are projected for presentation to the Board of Directors, and once approved by the board, management's problem becomes one of administration. If the plan is not met, management will have failed. If the plan is successfully executed, it will be a successful management. The basic problem is for each phase of the operation to do exactly what was planned. Those who can contribute towards making the plan work will advance rapidly in the field of management. Those who believe they can improve on a plan which is functioning satisfactorily will do well to guard against unbalancing an otherwise workable plan.

Where errors in the plan are creating bottlenecks in production, corrective measures will be needed immediately. Such variances should be vigorously ironed out. But where the plan is functioning according to schedule, it will be difficult to find receptive ears for improved efficiency, where such standards of efficiency are not essential to meeting the plan. Also, a changed method and lower piece rate may have little significance when measured against the major intangibles of morale and labor relations, which factors could easily unbalance all planning. The armor of technical correctness is not understood and is wholly inadequate when dealing in labor relations problems.

Then, too, certain labor problems such as finding additional work for the operator may be created. If additional work is not available, part time work will result, and this raises the question of the operator's rights under seniority. Here, someone's income is adversely affected and the union has no alternative but to exercise every means to restore it. The work originally offered has been, in part, withdrawn and the operator sees this as management's attempt to eliminate his position and his right to work. Actually, through proper planning, the work withdrawn would never have existed and this area of difficulties would be substantially reduced. The time is rapidly passing when the time and motion study man can expect management to hold the foreman responsible to make use of available workers' time developed by the time-study man through piece-meal methods improvement. In addition, a change to improve efficiency of but a single operation in a balanced production sequence, where that operation is functioning according to plan, may add to the problem of inventory control, material handling, scheduling, and loss to balance, for the reason that the materials would have to be accumulated both ahead of and after the operation. This does not imply that progress is not possible, but rather points to the importance of timing the improvements in efficiency to assure their adoption in an orderly manner and under conditions which will assure that a minimum of secondary problems will arise.

The importance of working the plan may not be over emphasized, and the doctrine of plan-your-work and work-your-plan should be thoroughly instilled in the minds of every member of both the line and staff management team. The Industrial Engineer need look no further for his starting point in making a genuine contribution in assisting management. Each foreman, supervisor and superintendent needs the assistance and guidance, and frequently the teaching available to him through the Industrial Engineer. However, they will not call upon this reservoir of knowledge as long as the Industrial Engineer believes that his value is measured from the methods improvement and cost savings report. This viewpoint on the part of the Industrial Engineer places him in direct competition with the line management. As a result of the Industrial Engineer's reports of improvements or potential improvements to higher echelons in the organization, the line man feels that the Industrial Engineer is casting a reflection on his ability or is undermining his position, or that he is being worked over by a member of the inspector general's staff. Let us remember our intent and purpose, and resolve to attain our objectives by being an assistant and consultant to the members of the line organization. Competitive feelings will be dissipated and aggressive team work will develop as the line organization is made to realize that a common objective exists; namely, to meet the commitments of the plan, and that success of all who are involved may be further assured through full use of the Industrial Engineer. Recognition from top management will accrue to all who participate in the successful operation of projected plans.

Second, the Industrial Engineer can further his preparedness to provide an axis for management by actively participating in planning. Although planning is generally left to the line organization, the Industrial Engineer will have an opportunity to participate in new planning if he is successful in assisting management in meeting the commitments of existing plans. If he is not invited to participate in the planning, it is his responsibility to develop the relationship which will bring forth this invitation. When his opportunity is developed, he should know his line man well and not incorporate in the planning bold elements so advanced they would disturb the newly placed confidence or tax the line man's imagination.

This is, however, his opportunity to incorporate into the new planning most all of his observed opportunities for methods and efficiency improvements. From time to time, while a plan is in operation, the Industrial Engineer can review proposed changes for future planning with the line organization, and find favorable reception and generally prompt approval. The many improvements which are, individually, relatively unimportant when operations are on schedule, become part of a new, balanced plan for over-all advancement in departmental efficiency. Such changes will not have appeared on the monthly methods improvement report, but will have been filed and incorporated in future operations where all will benefit and none be criticized. However, the Industrial Engineer's position is not easy as a staff employee. He assumes the responsibility for improved efficiency. He uses tact and diplomacy to obtain permission to contribute. He will be blamed for that which is in error and will share his contribution with others. However, substantial improvement at logical times forcefully commands attention of top management, and as we have said, good management knows that such progress is not possible without close cooperation of all associated with the project. Normal inquiry by top management will readily reveal the one to be recognized for leadership and guidance. Therefore, his position, leaving a lot to be desired, at the same time offers excellent opportunities for rapid advancement through demonstrated ability in leadership. (Example) Charles McCormick, president of McCormick and Co., in his plan for multiple management, defines leadership as a "combination of characteristics in an individual which enables him to induce people to strive for a common objective."

During my career, I have always held that true leadership does not require a full measure of authority before it can function, and that a safe investment in authority is made in those who apparently have no need for it. During my experience as manager of Industrial Engineering departments, time-study men would present to me recommendations for methods improvements and cost savings, and request that I submit them directly to top management. Regardless of the merits of the recommendations, it was obvious that no purpose would be served in trying to force improvements upon the lower echelons of the organization through a direct appeal to top management. Top management, although having the authority, faces the same identical problem as the time-study man, in that those recommendations still would have to be sold to the lower organization. Management well knows that any plan forced upon subordinates could become inoperative through lack of interest and support, and reflect discredit upon the entire organization.

It therefore was necessary for me to inform the time-study men that in addition to conceiving improved efficiency, they had the additional responsibility of selling such improvements to the various department and section heads. For this reason, I have long considered that diplomacy and salesmanship were essential characteristics of an Industrial Engineer. I have also found that the ability to sell one's ideas to others is equally important in presenting one's views to the board of directors, or to the shop committeeman.

Our policy was to engage time-study men who to us appeared to possess potentials for higher positions, and then to advise them that they were engaged as time-study men for the purpose of learning who we were, how we operated, how our organization functioned, what we made and how we made it. They were advised that they could not find a more fertile field in which to test their ability as leaders, and that there was no position in the organization to which they could not aspire. It was stressed, however, that such positions would be attained primarily through the ability of the engineer to develop a following through leadership, and that the attainment of such positions strictly on the basis of seniority or technological proficiency was most unlikely. Those men who attributed their lack of progress to the need for more authority received approximately the same treatment as a frustrated salesman. This treatment is an entire subject within itself; however, such sales principles as anticipating objections, disposing of objections, and sales psychology were fully applied. In fact, those considered most promising for executive development but who also required development in the principles of salesmanship, were required to attend evening classes in salesmanship and sales psychology. On the other hand, in cases where the Industrial Engineer's technological recommendations lacked merit, no consideration was extended for sales training and they were promptly dropped from the program.

And finally, the Industrial Engineer can evidence his willingness to assume responsibility and convince management he is best qualified to provide an axis for manufacturing activities through a willingness to specialize. The general practitioner will be successful in serving small enterprise only after he has acquired sufficient years of experience involving the key functions of sales, manufacturing and finance. As in the medical profession, the specialist is the man who has devoted his learning and experience to one particular phase of the profession, and consequently has become an authority in that field. By becoming an authority, the Industrial Engineer is able to make a larger contribution, and to earn recognition at a much earlier date. He may specialize in processing and tooling, cost control and budgeting, time and motion study, systems and procedures, cost estimating, and many other segments of Industrial Engineering. He has an advantage over certain other professional men, in that he can select his field of specialization after he has accumulated sufficient experience to know in which field his interest lies, and in which he will be most likely to excel. And while specializing, he can pursue breadth of knowledge in certain other phases of the profession which are closer to top management, and thereby prepare for further advancement. Management can frequently assist in this decision by offering positions in the line organization where it believes the man to be best qualified. The engineer should not remain aloof to management's problems in staffing the line organization, but should encourage management to select its members from among the Industrial Engineers.

Where can management find a better source or more fertile area in which to plant the seeds for the full growth and development of its future executives than in the Industrial Engineering field?

It may be interesting to digress here for a moment and turn our attention to the important problem of future management personnel.

The apparent shortage of executive and management talent has reached the proportions that such prominent publications as FORTUNE and MODERN INDUSTRY make monthly reference to the urgency of the situation with specific emphasis on the immediate future. Indeed, the subject has even reached such general interest publications as AMERICAN magazine and SATURDAY EVENING POST. It is difficult for me to believe that an actual shortage exists in ambitious men with the character and courage to prepare themselves for positions of responsibility.

Frequently, I wonder if a shortage actually exists or if management is failing to recognize the potential sources for such material; or, still further, finding promising material if they have a specific plan for its systematic and thorough development. Time is required to provide proper training and seasoning of executive material, and if management seeks a short course for converting young engineers into corporate presidents, I would be the first to confess I can conceive of no such scheme. I am acquainted with several plans for the expenditure of substantial sums for the training and development of young men for managerial positions. Such plans appear to have a singular inherent weakness, in that they provide for teaching and observing but provide limited opportunity for experience through doing.

Under these plans, only the exceptional individual will show marked progress, and the average prospects for future management will be lost in the mill. Under these circumstances, I can see where management would be alarmed at the apparent shortage of executive material, since there are so few young men who possess such exceptional qualities. Like the search for precious stones, seldom is one found which is so rare in its lustre and perfection that it commands the immediate attention of the collector. However, it is the average stone that provides the basis for commerce in precious jewels and, although appearing rather crude in their natural state, they frequently prove to be of exceptional value once properly cut and polished.

The time-tested plan for learning through doing eliminates the need for large expenditures without immediate return, and inasmuch as it has produced the executives of today, there is no reason to assume that with improvement and modernization, it will not produce the caliber of executives needed for tomorrow. Planned programs of this nature can be devised for young men in all phases of the enterprise. The plan will operate equally well in the fields of finance, sales, manufacturing, industrial relations or engineering.

Inasmuch as these remarks are addressed primarily to management, and we have selected manufacturing enterprise as our preferred example, let us explore the possible stages for training executive material in the manufacturing organization. A young promising Industrial Engineering graduate would logically begin in the time-study department. Here he would learn through observation and analysis of the various types and kinds of machinery and equipment, their capabilities and limitations; tooling, jigs and fixtures, both their proper and improper design; methods and work simplification; wage incentives, labor costs and excess costs; supervision, both its effectiveness and the possible lack of adequate supervision; labor relations and problems with labor representatives; material handling, scheduling, and the general organization of the manufacturing plant. While learning of these factors, he also will be learning through active participation in establishing labor standards or incentive rates. Following his tenure in this position, he may logically be transferred to the methods and processing department. Here he will learn of production planning and control, standardization and problems of mechanical tolerances, plant layout for efficient handling of materials in process, the design of proper tools, jigs and fixtures, quality factors and quality control, and here he will have his first contact with the section of the organization responsible for product and product design. Here again he will be learning through active participation in actually preparing the necessary processing instructions, by whatever name you may call them.

From here he may logically proceed to a position of cost estimating where he will have his early contacts with sales and sales problems, and management problems having to do with the over-all planning for profits. He also will have his first contact with accounting and budgeting, and will have more advanced association with product engineering. Here he will experience the broad aspects of management and realize the need for strength of character while endeavoring to influence large groups of people in coordinating planning towards common objectives.

From this position, it is management's responsibility to select the one of several channels holding the most promise for the individual. During the course of training through doing, the training director may prescribe supplementary studies which his observations dictate are needed to produce the well-rounded executive. Under this plan, the cost of training and development may be negligible, because, if the individual fails to continue to grow in accordance with expectations, he may then be retained at the level in the organization which is in keeping with the final determination of his abilities. Those who demonstrate ablity not only in technological proficiency, but in leadership, along with capacity for bearing responsibility and comprehension of effective management, may continue to progress into executive positions of the future.

In the smaller organization, the plan will still apply. But, as would be expected, the trainee's duties and responsibilities may, while still in logical sequence, involve more than one function at a time. Although the experience obtained may not be as broad as that in the larger corporation, it would still be adequate to satisfy the executive requirements for that particular or a similar enterprise.

The development of management personnel to meet management's present and future needs is related to our subject in that a properly organized Industrial Engineering department provides training area for developing future executives.

Returning to our main subject, let us now review a case history involving the development of an organizational structure, which provided a maximum degree of control for management, through the use of Industrial Engineers and at the same time provided training area for management material.

During the late 20s, the Victor Talking Machine Company at Camden, New Jersey, selected certain men from manufacturing or tool design who had exhibited ability to comprehend generally what was taking place in the manufacturing operations, and assigned them to the very important position of cost estimating. The estimators were required to advise management as to what the products would be expected to cost in production as they were released from the engineering department. They had no responsibility to meet costs once the product was released to manufacturing, and they defended their judgment only through logical reasoning in explaining variances to management. In order to better tie down the fluctuating cost-of-sales figure, it was decided in the early 30s to transfer the responsibility of cost estimating to the production departments. The drawings as released by the engineering department were distributed to the various sections of manufacturing and they submitted cost estimates indicating what the various parts would cost when produced in their respective sections. Under this plan, manufacturing could be held directly responsible for meeting its estimates. Each department, being self-sufficient, approached its objective without full consideration of the problems and difficulties which might arise in subsequent operations and departments. Each in its desire to present to management the lowest possible cost, found certain minor changes and substitutions desirable and practical. Before adopting such changes, they wisely cleared all proposals with the product engineering department.

Product engineering reviewed the recommendations soley from the standpoint of their effect on functioning characteristics, and logically accepted explanations that the recommendations were made in the interest of simplifying manufacturing processes. When production was started, it frequently developed that subsequent operations performed in other departments were estimated incorrectly, for the reason that other departments had no knowledge of the contemplated changes in preceding operations. Actual production was frequently delayed, certain materials in process were necessarily scrapped, and engineering was frequently directly introduced into manufacturing to effect changes which would salvage the situation and keep loss to a minimum. This lack of coordination between the various departments becomes more understandable when you consider that the physical facilities involved some 25 or 30 buildings, each five to 10 floors high, occupying approximately eight city blocks.

Needless to say, the sales department failed to deliver product to the distributors in time to meet their commitments to dealers, and the entire sales lagged behind schedule. A loss on operations for the period obviously appeared. The Radio Corporation of America, having acquired the Victor Talking Machine Company, became fully aware of this unsatisfactory situation, which was most forcefully revealed as the mechanical phonograph was converted into an electronic instrument, and radio receiver line production was started.

A series of conferences were held between the various division and section heads for the purpose of devising a means of providing management with estimated costs of production which would be within a small percentage of the actual cost experience, and at the same time provide detailed explanation of the variances between the cost estimate and production. I had the good fortune to attend these conferences.

Once the problem was defined as to its true ramifications, remedial action was obvious through the application of logic. The problem was to communicate the thinking and planning of top management into controlled, positive action and the logical solution was to develop a practical working relationship between top management and all points of manufacturing conversion. The plan devised was simple, but being a new conception in management control, it appeared radical and was adopted with certain reservations.

The functions of time study, preparation of process sheets, design of tools, production planning and scheduling, cost estimating, and finally cost control were physically assembled at one point in the manufacturing plant, and the heads of each function reported to a single manager who, in turn, reported to the vice president in charge of manufacturing. The new department had the responsibility of counseling top management while plans for operations were being formulated. It participated in such decisions as daily production rate, location where product could be best manufactured, starting date of production and available plant capacity, the need for additional or re-allocation of facilities, and many other decisions involved in over-all basic planning. With these determinations made, they were required to work out in complete detail coordinated plans for the manufacturing activities. These plans were developed with close cooperation of the engineering and manufacturing divisions. It was not the purpose of this new department to dominate this phase of the program, but rather to encourage the free exchange of thinking between all parties concerned, and then to develop the best possible plan which could be devised from the collective thinking of the group. The result of this work was dependable cost estimates which were based upon fully developed and operative plans. Once the plans and the estimates were accepted and approved by top management, the new department had the responsibility for placing the plans in motion, at the time, and in the manner determined through the conferences with top management. In placing the plans in motion, all details had been examined and resolved in advance. Therefore, it remained for the new department to disseminate throughout the organization specific instructions, all of which had received unanimous approval prior to their incorporation into the estimates. The manufacturing department was not permitted to deviate arbitrarily from the specified procedures, and the new department was held responsible for the practicability and workability of the manufacturing plan and processes. However, it had no jurisdiction over manufacturing or engineering personnel and consequently it was neither a line nor staff segment of the organization.

Although it is not possible to review in detail at this time all the advantages derived from the new department, the changed relationship between product engineering, manufacturing and the Industrial Engineering activities is of promary interest. The referred-to axis or central clearing house was quickly recognized as a point where most problems could be promptly resolved. For example, the engineer in the product design division no longer found it necessary when designing a particular component to consult with the manufacturing superintendent, the tool designer, the purchasing department and the process engineer to determine the availability of machinery, tools and materials and whether economic factors were favorable to his newly conceived component. Instead, the design engineer worked closely with the new department whose responsibility it was to determine all such factors for him, and make a record for future refer-

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Job Hunting Made Easy

By M. T. HEADED—B.S.

Following my graduation last month, I decided to put all my training into full effect (the B.S. is in I.E.)

I spent several months developing this foolproof plan for finding a good job. It is so good and my success is so assured, I want to pass this sure fire plan on to other less fortunate fellow professionals.

I chose to approach Company "X" . . . a fine firm, 107 years old, steady and conservative. They make Wing Bats. I know this plant very well. As a junior in college, we made a plant tour through the entire place. The working force consists of 1,000 men and an office staff of 50; top management consists of President, Vice-President in charge of manufacturing and Vice-president in charge of sales.

Here's how I'm going to approach them—(I have a job interview tomorrow).

Let me reconstruct what I'm going to say.

"You folks have an average working force of 1,000 men. I'm going to show you, with absolutely proven facts, how I can drastically reduce your costs, increase production and improve quality with just a fraction of the number of people to which you are accustomed. Let me carefully document this for you.

1. Method improvement and establishment of incentives.

Mr. Segur claims in a Production Handbook by Alfred and Bangs, (Ronald Press 1946) that "rate revisions are rare (after method analysis and incentive establishment) and that average increase and output per man hour over a wide range of operations has been 70%."

I ask you gentlemen, how can you ignore an invitation for savings such as that?

Mr. Schumard said in his primer of time study "from compiled industrial data covering many plants that have attractive wage payment incentive plans which result in excellent quality of product at low unit cost, it was learned the group average speed of the operators in each plant was 33 1/3 faster than normal."

You might say, gentlemen, that these men being consultants are claiming naturally that their work will result in success. Let me further document this.

2. The National Industrial Conference Board (Studies in Personnel Policy, #19) made a survey in 1948 which indicated that of the companies polled having an approximate employment of 5,000,000 workers, 51.7% employing 2,655,000 workers, used wage incentives.

This indicates to me, gentlemen . . . that what these consultants have to say is not theory but is factual.

I certainly think with my training, conservatively speaking, we might reduce your working force of 1,000 by 40%. Furthermore, there are many other important people who think highly enough of this and I'm sure you will not want to ignore it. For example, Lum in Mechanical Engineering (Vol. #60) says "Wage incentive is recognized as one of the most potent and dependable stimulants to increase production of wealth."

Gentlemen, if we might assume that the average employee earns $4,000 a year, already I have indicated how I can save you $1,600,000. Let's look at this table. Here's how the balance sheet looks now:

No. of Employees = 1,000
Save Thru Method & Incentive Work = 40% or 400
Total Work Force Now Required = 600
Total Savings = $1,600,000

There are many other scientific applications which can be applied. For example—

3. Monotony—We know that uniformity in working procedure is more monotonous than variety because a study made by the Great Britain Industrial Health RES Board (Reports 56 & 52) indicates that variation in job content on the process of making cigarettes by hand indicated "the varied method of procedure is an approximately 9% higher level than that for the uniform method."

This means then, gentlemen, that by careful job study and alternating men from job to job, we can save another 9%. As you can see by the total, the average work force has now dropped to 544 and we have picked up an additional yearly savings in salary of $224,000.

No. of Employees = 600
Save Thru Elimination of Monotony = 56
Total Force Now Required = 544
Total Savings Now = $1,824,000

4. Rest Periods—We also know that individuals working tend to accumulate fatigue and it is natural for these workers to seek relief. Anderson as quoted in Alfred & Bangs Production Handbook indicates that his study of 8,300 hours of work without rest period versus a study of 2,973 hours of work under the same conditions but with rest period, led him to this conclusion—from 12% to 15% or more of the time is used for rest or duties incidental to the main task. We might conclude from that that when rest periods are introduced we ought to be able to save 12-15% just by the establishment of rest periods. Frederick W. Taylor in his Principles of Scientific Management also recognized the fact that where strength on the job is demanded and cannot be eliminated "then the special treatment of frequent rest periods, very high incentives, etc. must be incorporated." You will note these are the very scientific principles we are advocating.

Great Britain Industrial Fatigue RES Board (Report 32) indicates a study on 8 girls engaged in folding handkerchiefs. Observations were made on these girls for three weeks with rest periods and without rest periods. Their conclusions are that the rate of work was increased on an average of 5%. With facts like these, I think we might safely guarantee rest periods resulting in at least an 8% improvement (43½ persons saved). Now let's look at this summary:

No. of Employees = 544
Savings Thru Rest Periods = 43.5
Total Force Now Required = 500.5
Savings a year = $ 174,000
Savings Now Total = $1,998,000

5. Diet — Dr. Hackert of Yale Univ. report in Meehanical Engineering (Vol. #58), that he tested 20 operators in a shoe factory who had been averaging 175 shoes an hour when they had taken 3 regular meals a day. These periods were given two extra meals consisting of milk and cake and production jumped up to 193 shoes an hour for an approximate 10% increase.

With facts like these, I would suggest that we serve the remaining men coffee and cake twice a day and in so doing we should be able to save an additional 50 people with the resulting yearly annual savings of $200,000.

Here's how the total looks now:

No. Employees = 500.5
Save = 50
New Work Force = 450.5
Save yearly = $ 200,000
Total Savings = $2,198,000

6. Factory Conditions—Anderson reported in Alfred and Bangs Production Handbook that "loss of production due to excessive summer temperature

was generally around 2%, rarely over 5%." To be conservative, let's figure a savings of 3% when we air-condition the shop (which I thoroughly endorse).

Our figures now will look as follows:

Old Work Force = 450.5
Save = 13.5
New Work Force = 437
Save Yearly = $ 54,000
Total Savings = $2,252,000

7. Job allowances—For an added bonus, let me throw in this savings. I understand you folks use a varying allowance for your jobs to cover fatigue, personal and unavoidable delays. A telephone call to your time study department indicated that these range from 20% to 60%, an average of 40%. Let me quote Mr. H. B. Maynard whose "production studies and analyses of incentive earnings" concluded that an over-all allowance of from 10% to 15% for ordinary factory work is sufficient to cover fatigue, personal and unavoidable delays. That being the case, I can see absolutely no reason why we shouldn't substitute 15% instead of the average 40%, thereby netting you a 25% savings on the remaining payroll of 437 people. In payroll if each person earned an average of $4,000 a year, this would mean savings of an additional $432,000 free of charge and yours for the asking. Our savings summary now looks like this:

Old Work Force = 437
Save = 108
New Work Force = 329
Annual Savings = $ 432,000
Total Savings = $2,684,000

8. Distractions — We note that research by Fere, Tartchanoff, Scripture, Gretry, Hyde and Scalapino indicate that the right sounds can increase muscular energy and increase or decrease the pulse rate. Further, research by Kravka, Diserens, Ubantschitsch indicate that the right sounds can increase the threshold of sensory perception especially significant in precision work. Musac Inc. (one outfit which provides music for industry) shows a chart which indicates an approximate 11% increase in efficiency in a before and after chart that showed what happened when music was installed.

I think we would be stupid to ignore this and, consequently, for the small amount involved we should install it. The resulting 11% increase will save us the salary of 36 more people with the resulting yearly savings of $144,000.

Old Work Force = 329
Save = 36
New Work Force = 293
Yearly Savings = $ 144,100
Total Savings = $2,828,000

9. Factory turnover — We would guess that turnover in your plant would be indicative of the rest of the industry — approximately 10%. This means that of the present work force of 1,000 at least 100 men are carried as reserve to replace turnover. We know we can eliminate turnover. Factory Management and Maintenance (Vol. #95) told the story of a spinning department of a Pennsylvania Textile Mill which had a 250% labor turnover in a year. Workmen in the spinning department complained of neuritis, foot trouble and melancholia. Management established a compulsory period of 10 minutes out of every two hours when everyone was required to lie down and relax. The result was that complaints were eliminated, production was increased so the bonuses were earned and, at the end of the first year of this procedure, there has been practically no labor turnover. It would be my suggestion that we provide floor mats for all individuals so that they can lie down for 10 minutes every two hours. We will, thereby, save 100 people on the force. Salary for 100 people thus saved will add to $400,000 savings a year.

Old Work Force = 293
Save = 100
New Work Force = 193
Yearly Savings = $ 400,000
Total Savings = $3,228,000

10. Noise elimination—Kennedy in his research on noise says "Noise interferes very seriously with the efficiency of the worker. It increases tension and makes concentration upon set tasks difficult. The first effect of noise is one of disturbance, of excitation and of irritation. These effects have consequences from many kinds in conduct. They cause loss of temper, they play a part in quarrels, and they prevent deep and sustained thinking. In attempting to overcome the effects of noise, great strain is put on the nervous system leading to neurasthenic and psychosthenic states." It is obvious to me that the decibel level in your shop is considerably more than 80 (which would be very heavy street traffic). It would be my recommendation that we institute a noise prevention program to move this down to at least 50 (which approximates that of a quiet automobile). I would estimate (and I must admit that these are my own figures) and all my research indicates that we might expect at least an additional 10% improvement in production because of this. The effects of instituting a noise program would then remove 19 additional people from the payroll and save you $120,000 more a year.

Old Work Force = 193
Save = 19
New Work Force = 174
Yearly Savings = $ 76,006
Total Savings = $3,304,000

11. Lighting—I couldn't help but notice (when I toured your plant last year) that you used incandescent lighting. I would estimate that the level of light in the plant is much less than desirable. Alfred & Bangs in their Production Handbook indicate that improper illumination is responsible for from 10 to 15% of the total nervous energy expended in the work. It would be my suggestion that we install fluorescent fixtures over every work bench and across each aisle. This, then, would raise the level of the lighting in the plant to remove the source of nervous energy expended in work. Accomplishing this ought to allow us the downgrade of all jobs by a fair figure of at least 12%. This would have the effect of eliminating an additional 21 persons and saving you $84,000 annually.

Old Work Force = 174
Save = 21
New Work Force = 153
Yearly Savings = $ 84,000
Total Savings = $3,388,000

12. Absenteeism—Absenteeism for a plant of your nature is probably something slightly less than 6%. No less a person than Dr. Lillian M. Gilbreth from extended experience indicates that the effect of the employment of the handicapped is now more than an incidental consideration in industry, and recommends that you give it your most careful attention. We know that Ford Motor Co., Eastern Aircraft Co., Armour Co., Caterpillar Tractor Co., RCA Victor Co., General Motors Corp., Goodyear Tire & Rubber Co., Vultee Aircraft and many others are some of those who are following definite policies for successfully employing handicapped workers. We see no reason why we can't replace nearly 50 to 60% of the jobs in the plant with handicapped workers, thereby reducing this 6% absenteeism factor which will allow us an additional sav-

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Industrial Engineering and Operations Research —A Critique

By FRANK M. GRYNA, JR.
Asst. Prof. of Statistical Quality Control, Rutgers University, formerly Instructor of Industrial Engineering, New York University

"We Industrial Engineers seem to want to sit back and glory in our accomplishments instead of broadening our horizons and doing a more effective job. Maybe we suffer from smug complacency." These words are from a recent editorial by Dr. Robert N. Lehrer, editor of this Journal. He is right! Perhaps Operations Research will wake us up to this reality.

The purpose of this article is to discuss the significance of Operations Research to Industrial Engineering. The writer feels that there are important implications not appreciated by the average Industrial Engineer. The easiest way to approach the problem is to discuss the relations between Operations Research, Quality Control, and Industrial Engineering.

First, let's briefly examine the background, methods, and scope of Operations Research (O. R.). O. R. began in England during World War II when the government asked a group of scientists to help decide the most effective use of the small amount of personnel and equipment that England had at the start of the German blitz. Successful results prompted the American military people to organize some Operations Research teams. Our teams worked on such problems as deployment of planes to hunt for enemy subs and determination of ship routes to minimize the probability of being hit by torpedoes. With the end of the war, O. R. people began to consider the possible industrial applications. We can examine the methods of Operations Research in relation to an industrial application of concern to Industrial Engineers.

Operations Research can be defined as [1] "a scientific method of providing executives with a quantitative basic decisions regarding the operations under their control." In solving a problem in O. R., the analysis is made in three steps:

1. Determine a "measure of effectiveness."
2. Determine a "working model."
3. Decide on a basis for a decision and make the decision.

For example, [2]suppose a part of a machine is held in place by two bolts. If only one bolt breaks, the machine will still operate but the life of the second bolt will be shortened. To replace this one broken bolt would take 2 hours. If both bolts break, the machine will stop and it will take 20 hours for repair. Should there be a periodic inspection program to replace one broken bolt so that both don't break and result in 20 hours downtime? How often should there be an inspection? Solving by the above steps:

1. Our goal is to have the machine down as little as possible. In deciding on a solution, we can work with percent downtime as the criterion or measure of effectiveness.
2. The working model is usually a mathematical equation. In this example, percent downtime would be expressed as a function of the inspection interval.
3. The basis of a decision would be minimum downtime. We can differentiate the equation and solve for the inspection interval that will yield a minimum value of percent downtime.

You may have noticed that this is merely an example of the minimum cost type of problem from engineering economics. If with increases in the value of some variable, one cost increases as another cost decreases, then there is some value of the variable that will yield a minimum total cost. As a practical matter, the equation is usually too difficult to determine. The Industrial Engineer recognizes this and solves the problem by trial and error which, for these types of problems usually takes less time than finding the equation and differentiating. We assume several values of the inspection interval and solve for the corresponding downtimes. The interval which yields the lowest downtime provides a practical answer to the problem. O. R. has also been applied in the same manner to compute the most economical size of production runs — an old Industrial Engineering problem.

The example cited does not illustrate the scope of the O. R. field but is definitely a typical example of the O. R. approach to manufacturing problems. To indicate the broad scope of the whole Operations Research field, here are a few other examples:

1. Scheduling of production and maintenance of inventory for minimum cost.
2. Evaluation of advertising to determine what percent of a total advertising budget should be allotted to each of several products.
3. Evaluation of the effectiveness of a chain of retail outlets on overall company operations.

Now let's fit Quality Control into the problem. The field of Statistical Quality Control began in 1924 when Dr. W. A. Shewhart developed the control chart as a means of controlling the variation in a process. Practical application was limited until World War II. In the postwar period, Quality Control really came into its own and is currently riding on a prosperous crest of success.

Encouraged by their results on the quality problem, some Quality Control people began to apply their statistical techniques to other problems—e g. accident prevention, analysis of sales data, etc. The fact that statistics is a part of the O. R. kit of tools has attracted some Quality Control people to Operation Research. To those Quality Control people who are eager to try their hand at other problems in management, the label of O. R. is appealing because of the broad scope of problems that O. R. hopes to cover. The writer looks dimly on such aspirations because of the slim training or experience in management problems on the part of the majority of Quality Control people. It is a fact that many Quality Control people are engineers or pure scientists who were suddenly thrown in Quality Control when management decided to set up a program. They learned while doing — and while making mistakes. Will the same events take place with O. R.? The writer knows of one large company whose Quality Control department is being handed problems in Operations Research.

Now what is the relation of I. E. to O. R. Notwithstanding the constant claim of the O. R. people that there is a difference, it is difficult to distinguish between the two fields. Of no little consequence is the fact that neither field has been able to define itself.

A comprehensive student report[3] from the Harvard Graduate School of Business Administration states "It is sometimes difficult to differentiate Industrial Engineering from Operations Research. The work that has been done in both fields is often confused. It is possible, however, to point out the following facts: Industrial Engineering is generally limited to manufacturing activities and in some cases to manufacturing and distribution operations. The industrial applications of Operations Research cover nearly all aspects of a business. Modern Industrial Engineering methods are primarily concerned with the applications of established tools to industrial problems. In Operations Research each problem is considered far too different from other problems to permit a mere application of established tools." (Some O. R. people like to differentiate Operations Research by emphasizing that a problem is attacked by an O. R. team composed of experts from a wide variety of fields such as mathematics, statistics, psychology, physics, econometrics, etc. The writer cannot attach any importance to this because I. E. research projects at many schools have often used teams of specialists from many fields).

Dean Robert H. Roy of Johns Hopkins has written a frank article on this subject.[4] He states, "Operations Research occupies the identical, unique organization relationship as industrial engineering, but its analytical staff role is capable of being infinitely more fruitful because its investigations are not bounded

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PREDETERMINED TIME STANDARDS IN THE ARMY ORDNANCE CORPS

By MARVIN E. MUNDEL and IRWIN P. LAZARUS
Ordnance Management Engineering Training Program

The Ordnance Corps of the U.S. Army has recently solved the problem of establishing a system of Predetermined Time Standards for its ninety-seven scattered installations in the United States and their 169,000 civilian employees. Rather than be forced to watch each installation enter into a contract with a separate civilian concern with the ensuing confusion of systems,[1] the Ordnance Corps is presently introducing a single system. This system was carefully developed in the typical industrial situation; it can be easily taught, is easily applied, and it appears to possess a smaller deviation from time study values than the widely sold systems to which it has been compared. The system is called Ordnance Predetermined Approximate Performance Times and as its name implies, is considered only a method of approximating the time required to perform manual jobs or the manual parts of jobs.

It is anticipated that the system will serve Ordnance in obtaining:

a. More efficient layouts for new work-lines prior to their establishment.
b. An additional check on time studies.
c. An additional tool for the determination of work loads.

No exorbitant claims are made for its accuracy, although constant effort is being made to accumulate data and determine the system's inherent deviation from time study values. No attempt is being made to oversell predetermined times in the Ordnance Corps, but instead to consider them as merely another tool in the fundamental equipment of the Management Engineer. The use of the Ordnance Predetermined Approximate Performance Times is presently being taught in the Management Engineering Training Program at Rock Island Arsenal, a central school serving the entire Ordnance Corps. Already, enrollees from fifty-two installations have received this training as part of the course in Work Measurement. It is important to note that these trainees are also being taught methods of stop-watch time study and statistical manpower control to give three approaches to the problem from which they can choose as necessary. The approaches compliment rather than being interchangeable and rather than replacing each other.

Development of the System

The Ordnance Predetermined Times, as well as all standard data of wide applicability, may be defined as tabulated values from many previous studies, from which values may be selected and totaled to synthesize the time for a job. It is the level of accuracy of the previous studies, and the validity of the method of synthesizing and totaling the values that controls the final validity of any system. This is believed to be a superior system because of the degree of control exercised.

A. In respect to tabulating previous data:
   1. The recording of accurate times.
   2. The careful measuring of all physical dimensions.
   3. The proficiency level of all operators chosen.
   4. The accuracy of the equipment used.
   5. The improved rating procedure used throughout.
   6. The statistical validation of all recorded times.

B. In respect to synthesizing and totaling:
   1. The greater variety of possible values which may be selected.
   2. The greater objectivity of the criteria used to select values from the tables.
   3. The greater use of continuous data rather than large step, discrete data so as to more closely approximate the continuum of job difficulties actually encountered.
   4. The use of a method of allowing for the interaction of small motions in an element rather than treating them as independent values.

The system was developed by collecting a considerable series of time studies of industrial operations using a synchronous-motor-driven Kodak Cinë Special movie camera. All operations were performed by fully trained, highly skilled, industrial operators working near or above standard performance in 3 industries (electrical metal-working, and plastics). A minimum of twenty-five cycles (with as many as forty cycles) was recorded of each operation. Prior to filming, sketches were drawn, showing all motion distances and work place dimensions. Still photographs were also taken to further fix details of the work areas. The films, exposed at one thousand frames per minute, were rated by an experienced group against a twelve pace multi-image loop. Films of every job cycle were then analyzed and timed using a breakdown into therbligs. The reliability of each therblig time sample was checked using a statistical technique commonly employed for reliability of averages.[2] The variables affecting the categories of therbligs were next isolated and evaluated.

Determination of Therblig Variables

Each therblig was sub-divided into categories. The categories were chosen on the basis of statistically significant variables that affected the time for the performance of each therblig. Further, the categories were made highly definitive so that they might be easily differentiated by the user, giving consistency of results from one individual to another and over long periods of time. Categories were determined and times tabulated for only seven therbligs since these were the only ones considered essential to any system of easily applied pre-approximated work times.

These therbligs are:

1. Transport empty (TE)
2. Transport loaded (TL)
3. Grasp (G)
4. Position (P)
5. Assemble (A)
6. Disassemble (DA)
7. Release Load (RL)

Determination of TE and TL Time Table

It has already been shown by Deegan[3] that for any hand motion the first forty per cent of the time of motion is spent in acceleration, the second twenty per cent is spent moving at constant velocity, and the third forty per cent is spent in deceleration. These proportions are the same for all paces and exist whether the hand is moving in the empty or loaded condition. This can be represented by:

Acceleration
40% T
Constant Velocity
20% T
Deceleration
40% T

Under the conditions of uniformly accelerated motion it is accepted that:
for accel:
for constant
velocity

$s = v_i t + \frac{1}{2} at^2,$

$s = v_c t,$

where $s =$ distance traveled
$v_i =$ initial velocity
$v_c =$ constant velocity
$t =$ elapsed time
$a =$ uniform acceleration.

Let $S =$ the total distance moved during the three periods and let $T =$ total time, then

$$S_{total} = \overset{.40T}{(v_i t + \tfrac{1}{2} at^2)} + \overset{.20T}{(v_c t)} + \overset{.40T}{(v_i t + \tfrac{1}{2} at^2)}$$

where the first term takes place for 40% of the total time, the second term takes place for 20% of the total time and the third term takes place for 40% of the total time.

Inserting the above percentages of time into the appropriate terms we get:

$$S_{total} = [v_i\,(.40T) + \tfrac{1}{2}a\,(.40T)^2] + [v_c\,(.20T)] + [v_i\,(.40T) + \tfrac{1}{2}a\,(.40T)^2]$$

Assuming the hand motion to start from rest, v_i in the first term becomes zero. Also, v_c in the second term can be equated to the velocity existing at the end of the first period. Let us call the velocity at the end of the first period v_f.

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[1] Ordnance Corps Bulletin No. 21-53, 17 Sept. 1953.

[2] All Basic data and calculations may be found in "A system of Predetermined Human Work Times," Lazarus, Irwin P., Ph.D. Thesis, Purdue University, 1952.

[3] Deegan, Wayne, "The Development and Use of a New Technique for Measurement in Time and Motion Study," M.S. Thesis, University of Iowa, 1935.

We can find v_f by:

for 1st period $v_f = v_i t + at$

but $v_i = O$, so

$v_f = at$

t for 1st period $= .40T$

$v_f = a(.40T)$

and $v_f = v_s$ of 2nd period.

so, $v_s = v_f = a(.40T)$.

Also, v_i the start velocity of the third period equals v_s of the second period (which equaled v_f of the 1st period) or $a(.40T)$. Further, a negative sign should be inserted in the third term to account for the deceleration condition. Thus:

$$S_{total} = [O + \tfrac{1}{2}a(.40T)^2] + [a(.40T)(.20T)] + [a(.40T)(.40T) - \tfrac{1}{2}a(.40T)^2]$$

which reduces to

$$S_{total} = .24\,aT^2.$$

In order to get the time T for each value of S, the constant acceleration was computed by averaging the a's arising from each pairing of distance and rated time for all observed occurrences of the therbligs, TE and TL. The average a was tested statistically and found highly reliable. Its value was 32.8 ft. per second² or more usefully, 1,415,000 inches per minute². With this latter value inserted in the above equation we get:

$S = .24\ (1{,}415{,}000)\ T^2$

$S = 339{,}700\ T^2$. (Equation A)

This equation (A), based on known physical theory, was tested by comparing it to the results obtained when a parabola was statistically fitted to all the empirical time values after rating for the therbligs TL and TE from all the jobs included in these studies. The curves were fitted in the manner that the sum of the squared deviations was a minimum and the resulting equation was:

$S = 321{,}000\ T^2$. (Equation B)

A six per cent discrepancy is represented by the difference between the constant A (deduced from the average acceleration a) and B (deduced from the equation fitted to the rated data).

A solution of the theoretically derived equation (Equation A) was tabulated for time values corresponding to one inch increments up to a maximum distance of 48 inches. (See Table 1, Basic Time Tables for these time values).

Determination of the Table for Grasp

The therblig grasp is defined as: A hand or body member gaining control of an object.

The therblig grasp was divided into four categories dependent only upon the physical attitude of the hand performing the grasp. These were the only four types observed and were each distinctly different uses of the hands. The names given to these four categories are:

a. Contact grasp
b. Contact-Pinch grasp
c. Pinch grasp
d. Wrap grasp

a) The contact grasp consists of gaining control of an object by touching the object or by striking the object (without using the fingers individually for pinching or curling around). Hence, the hand is used as a single mass, as in the case of striking a control lever, on the fly, to actuate it. Another example would be the control gained by sliding a box or washer along a table, the contact being maintained in this case by friction.

b) The contact-pinch grasp is an outgrowth of the contact type of grasp and always begins with the aforementioned striking or touching. After starting the object moving, however, the fingers gain further control by pinching the object, which is defined as existing whenever the fingers (one or more) oppose the thumb with an object in between. An example of the contact-pinch grasp is the sliding of a washer along a flat surface, followed by a pinching between the thumb and fingers. Another example of the contact-pinch grasp is the reaching for, striking, and gaining full control of a pencil when one is not watching that pencil. This type of grasp is usually associated with the correct use of lip bins for small parts.

c) The pinch grasp occurs whenever the hand gains control of an object by using the fingers (one or more) in opposition to the thumb with the object in between. An example of the pinch grasp is the picking up of a bolt or small casting which is lying directly in the field of view. It appears to make no difference whether the thumb and index finger alone are used or the thumb in opposition to all four fingers.

d) The wrap grasp occurs when the hand gains control of an object by having the fingers oppose the palm of the hand. Examples of the wrap grasp are the grabbing of a hammer handle, the grasping of the steering wheel of one's car, or the grasping of a machine handle or wheel.

During film analysis, all of the grasps observed were placed into one of the four categories. The rated times for those grasps were collected and tabulated into four columns (each value in a column was itself the mean of about twenty-seven cycle readings). Then the mean time for each of the four columns was determined. Finally an analysis of variance was performed to determine whether or not chance alone might have caused the observed variation between the column means. (All the column means were significantly different at the 1% level of confidence). Thus a time value was obtained for each of the four types of grasp. These results appear in Table 1, Basic Time Tables.

Determination of the Table for Position

The therblig position is defined as: A hand or body member causing the alignment, orientation, or specific location of a part or object, (as opposed to the change in gross location caused by TL).

The therblig position was found to divide, by the nature of the task, into five categories. This division was dependent upon the number of directions in which accuracy was necessary when locating the piece (or in which the tolerance of location was small). These categories have been named "degrees of restriction."

Degrees of restriction have been divided into two major types—locational and orientational. The locational degree of restriction occurs when an object must be aligned with respect to a point in space or to another mating object. Thus three locational degrees of restriction result.

1. When the object must be carefully located in the forward and backward (longtitudinally horizontal) direction.
2. When it must be carefully located in the vertical direction.
3. When it must be carefully located in the sideways (transverse horizontal) direction.

The three orientational degrees of restriction are concerned with the physical attitude of the object after it has been located at a given point in space. Since the aeronautical engineers have already been faced with the problem of describing the flight attitude of a body moving in air and have already built up an adequate set of descriptive terms, these were used in order to describe the orientational degrees of restriction.

1. If an object must be positioned so that very little deviation is allowed from the level (horizontal) attitude we can say that the position involves a degree of restriction called "roll."
2. If an object must be positioned so that very little deviation to the left or right is allowed in the direction of motion that the forward part of the object maintains, (about a vertical axis) we can say that the position involves a degree of restriction called "yaw."
3. If an object must be positioned so that very little deviation up or down is allowed in the vertical direction of motion that the forward part of the object maintains we can say that the position involves a degree of restriction called "pitch."

These six degrees of restriction are shown pictorially by Figure 1.

All of the degrees of restriction were considered as adding equally to the time of positioning. This may be an approximation but the data did not indicate any basis for differentiation. Examples of possible combinations of degrees of restriction are:

1. Zero degrees of restriction could be represented by the positioning of a marble over a bushel basket. In no direction is a small deviation a controlling condition. The positioning time of this type is negligible and is often followed by a "light toss" type of release.
2. One degree of restriction could be represented by a marble being positioned over a long, narrow, slot-like opening of considerable length. The marble would need to be aligned only in the sidewise direction (perpendicular to the slot) and then released. Vertically it has no restriction; along the length of the slot it has no restriction and, since the object is a marble, no orientational restrictions could

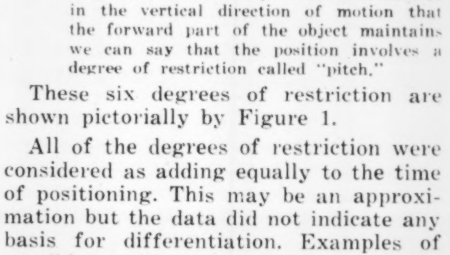

Figure 1. Degrees of Restriction.

apply. Thus only one degree of restriction remains transverse ,or longitudinal depending on the orientation of the slot.

3. Two degrees of restriction could be represented by the positioning of a marble over a deep vertical hole slightly larger in diameter than the marble. In this case the marble must be aligned in the transverse (sideways) direction and in the forward or backward direction, but always in the horizontal plane. No vertical restriction exists since the marble may be released as soon as it is over the hole.
4. Three degrees of restriction could be represented by the positioning of a hexagonal nut over a shallow recess of slightly larger dimensions. The nut would require alignment in the transverse (sideways) direction, in the forward and backward direction and also orientationally with respect to yaw since the hexagonal nut could not be rotated horizontally without forcing the corners out of alignment. The nut would be free in the vertical direction and also it would be free to pitch somewhat and roll somewhat and still find its way into the matching hole.
5. Four degrees of restriction could be represented by the positioning of a cylinder, end down, over a vertical hole slightly larger in diameter than the cylinder. The cylinder would require alignment in the transverse (sideways) direction in the forward and backward direction, but would be free in the vertical direction. Orientationally, the cylinder would be restricted with respect to pitch and roll but would be free to yaw about its vertical geometric axis (this is simply rotation).
6. Five degrees of restriction could be represented by the positioning of a cube into a congruent hole only slightly larger than that cube. Locationally, the cube would require alignment in the transverse (sideways) direction and in the forward and backward direction, but it would be free vertically. Orientationally the cube would be restricted in all three degrees of roll, pitch, and yaw.

Although there are six degrees of restriction possible when positioning any object, no more than five have been encountered in practice. All six degrees need be mentioned since any five degrees may be required for a given positioning. To apply all six degrees in a situation would require that the object not move whatsoever and hence could not be brought up to the positioning location, a situation not normally conceivable. One of the three locational degrees of restriction must be free to allow the operator to assemble the positioned piece. The piece, therefore, must be able to move either forward, sideways, or up and down when being assembled and such a situation will remove one of the three locational degrees of restriction, leaving five possible degrees remaining.

During film analysis, all of the observed position therbligs were identified and placed into one of the five categories depending upon the number of degrees of restriction. The times for these position therbligs were thus collected and tabulated into five columns (each value in a column again, the mean of approximately twenty-seven cycle readings). Then the mean time for each of the columns was determined. An analysis of variance was employed to determine whether or not chance causes alone could have caused the observed differences between the column means. All of the column means were significantly different at the one per cent level of confidence. In this manner a time value was obtained for each condition of from one to five degrees of restriction governing the therblig, "position." These results appear in Table 1, Basic Time Tables.

Determination of the Table for Assemble

The therblig assemble is defined as: A hand or body member causing matching or mating parts to go together. It starts when the mating or receiving member causes restricted motion of the piece being assembled and when the movement of that piece is completely guided. Thus, only pressure is required to complete the assembly and very little control over the piece is necessary once assembly starts. (Until the motion of the piece is completely guided by the mating member, it is probably correct to assume that positioning is still taking place). Assemble ends when the hand or body member has caused the parts to go together.

Since assemble is defined as beginning after the motion of the piece is completely guided and after the hand has imparted a starting velocity to the piece being assembled, it was hypothecated that during assembly the piece travels at a near constant velocity (being stopped short, of course, when junction is complete). Since a constant velocity would result in a direct proportionality between distance and time,

($V=S/T$, where V=constant velocity, S=Distance, and T=Time)

it was decided to fit a straight line to the time values for assemble.

A series of time values and a corresponding series of assemble distances (both from the film analysis) were fitted with a straight line using the method of least squares. The resulting equation was:

$$T=.005208D-.001719,$$

where T=time in minutes
D=distance assembled in inches.

This equation was solved and the results tabulated for the missing values (in respect to observations) for a series of distances from zero to three inches in length and in increments of 1/8 inch. This table represented the calculated times for the therblig assemble and appears in Table 1, Basic Time Tables.

Determination of the Disassemble Table

The therblig disassemble is defined as: A hand or body member causing parts which were together to separate. It starts when the hand or body member causes parts which were integral to begin to separate and ends when motion of the piece is no longer restricted by the mating member, jig, or fixture.

A proportionality between distance moved and disassemble time was assumed, as suggested from the results of assemble. However, analysis of the data showed no difference between the various times. Since no significant difference separated the values for the therblig disassemble, the mean time was computed and its reliability checked. The resulting high reliability seems to lead to the conclusion that disassemble can be accomplished in approximately the same amount of time independent of the distance moved, at least as far as measurable differences in time. These results appear in Table 1, Basic Time Tables.

Determination of the Table for Release Load

The therblig release load is defined as: A hand or body member relaxing control and letting go of an object.

The rated times for the therblig release load were originally divided into three categories dependent on the preceding type of grasp, provided it was still so controlled up to the moment of release. These were:

1. Contact grasp
2. Pinch grasp
3. Wrap grasp

(The contact-pinch grasp had been eliminated since it would always result in a pinch grasp at the moment of release).

From the film analysis, therblig times for these three categories of release load were obtained and tabulated into three columns. The mean of each column was computed and an analysis of variance was performed to determine whether or not chance alone might have caused the deviation between the means of the three categories. The differences did not prove to be statistically significant and it was concluded that the observed deviations were due to chance causes. Thus, it appeared to make little difference in the elapsed time for release load whether a piece is released from a wrap grasp, a pinch grasp, or a contact grasp. This result might be explained by concluding that release is simply an opening of the fingers (or a relax of the fingers) which consumes about the same time no matter how those fingers were grasping the piece.

All the values in the tables were therefore averaged and the resulting mean was used to represent the time for Release Load. This result appears in Table 1, Basic Time Tables.

Summary of Factors in Control during Determination of Therblig Tables

1. Only skilled, completely trained industrial operators were studied performing their usual tasks under normal industrial conditions.
2. All operator movements were measured prior to filming.
3. A synchronous motor camera drive was employed to give as constant a time-recording device as possible.
4. Ratings were made of the films prior to analysis to avoid unconscious biasing.
5. Reliabilities of mean therblig times were determined.
6. Curves were fitted by the method of least squares.
7. Resulting time differences were tested for significance.

Other Variables Affecting Therblig Performance

All of the above variables used in constructing therblig time tables constitute only a part of all the variables that affect therblig performance time. It is generally known that the time for performing a therblig is a function of at least:

a. distance
b. complexity of action
c. amount of body involved

TABLE I

BASIC TIME TABLES IN 1/100,000 MINUTES; (.00001 MIN)[1]

Time for TRANSPORT LOADED, TRANSPORT EMPTY, and WALKING

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
Distance (inches)	Basic Time	Bx 1.01	Bx 1.02	Bx 1.03	Bx 1.04	Bx 1.05	Bx 1.06	Bx 1.07	Bx 1.08	Bx 1.09	Bx 1.10	Bx .10	Bx .20	Bx .30	Bx .40	Bx .50	Bx .60	Bx .70	Bx .80	Bx .90
1	172	174	175	177	179	181	182	184	186	187	189	17	34	52	69	86	103	120	138	155
2	243	245	248	250	253	255	258	260	262	265	267	24	49	73	97	122	146	170	194	219
3	297	300	303	306	309	312	315	318	321	324	327	30	59	89	119	149	178	208	238	267
4	343	346	350	353	357	360	364	367	370	374	377	34	69	103	137	172	206	240	274	309
5	384	388	392	396	399	403	407	411	415	419	422	38	77	115	154	192	230	269	307	346
6	420	424	428	433	437	441	445	449	454	458	462	42	84	126	168	210	252	294	336	378
7	454	459	463	468	472	477	481	486	490	495	499	45	91	136	182	227	272	318	363	409
8	485	490	495	500	504	509	514	519	524	529	534	49	97	146	194	243	291	340	388	437
9	515	520	525	530	536	541	546	551	556	561	567	52	103	155	206	258	309	361	412	464
10	543	548	554	559	565	570	576	581	586	592	597	54	109	163	217	272	326	380	434	489
11	569	575	580	586	592	597	603	609	615	620	626	57	114	171	228	285	341	398	455	512
12	594	600	606	612	618	624	630	636	642	647	653	59	119	178	238	297	356	416	475	535
13	619	625	631	638	644	650	656	662	669	675	681	62	124	186	248	310	371	433	495	557
14	642	648	655	661	668	674	681	687	693	700	706	64	128	193	257	321	385	449	514	578
15	665	672	678	685	692	698	705	712	718	725	732	67	133	200	266	333	399	466	532	599
16	686	693	700	707	713	720	727	734	741	748	755	69	137	206	274	343	412	480	549	617
17	707	714	721	728	735	742	749	756	764	771	778	71	141	212	283	354	424	495	566	636
18	728	735	743	750	757	764	772	779	786	794	801	73	146	218	291	364	437	510	582	655
19	748	755	763	770	778	785	793	800	808	815	823	75	150	224	299	374	449	524	598	673
20	767	775	782	790	798	805	813	821	828	836	844	77	153	230	307	384	460	537	614	690
21	786	794	802	810	817	825	833	841	849	857	865	79	157	236	314	393	472	550	629	707
22	805	813	821	829	837	845	853	861	869	877	886	81	161	242	322	403	483	564	644	725
23	823	831	839	848	856	864	872	881	889	897	905	82	165	247	329	412	494	576	658	741
24	841	849	858	866	875	883	891	900	908	917	925	84	168	252	336	421	505	589	673	757
25	858	867	875	884	892	901	909	918	927	935	944	86	172	257	343	429	515	601	686	772
26	875	884	893	901	910	919	928	936	945	954	963	88	175	263	350	438	525	613	700	788
27*	892	901	910	919	928	937	946	954	963	972	981	89	178	268	357	446	535	624	714	803
28	908	917	926	935	944	953	962	972	981	990	999	91	182	272	363	454	545	636	726	817
29	924	933	942	952	961	970	979	989	998	1007	1016	92	185	277	370	462	554	647	739	832
30	940	949	959	968	978	987	996	1006	1015	1025	1034	94	188	282	376	470	564	658	752	846
31	955	965	974	984	993	1003	1012	1022	1031	1041	1051	96	191	287	382	478	573	669	764	860
32	971	981	990	1000	1010	1020	1029	1039	1049	1058	1068	97	194	291	388	486	583	680	777	874
33	986	996	1006	1016	1025	1035	1045	1055	1065	1075	1085	99	197	296	394	493	592	690	789	887
34	1001	1011	1021	1031	1041	1051	1061	1071	1081	1091	1101	100	200	300	400	501	601	701	801	901
35	1015	1025	1035	1045	1056	1066	1076	1086	1092	1106	1117	102	203	305	406	508	609	711	812	914
36	1029	1039	1050	1060	1070	1080	1091	1101	1111	1122	1132	103	206	309	412	515	617	720	823	926
37	1044	1054	1065	1075	1086	1096	1107	1117	1128	1138	1148	104	209	313	418	522	626	731	835	940
38	1058	1069	1079	1090	1100	1111	1121	1132	1143	1153	1164	106	212	317	423	529	635	741	846	952
39	1072	1083	1093	1104	1115	1126	1136	1147	1158	1168	1179	107	214	322	429	536	643	750	858	965
40	1085	1096	1107	1118	1128	1139	1150	1161	1172	1183	1194	109	217	326	434	543	651	760	868	977
41	1099	1110	1121	1132	1143	1154	1165	1176	1187	1198	1209	110	220	330	440	550	659	769	879	989
42	1112	1123	1134	1145	1156	1168	1179	1190	1201	1212	1223	111	222	334	445	556	667	778	890	1001
43	1125	1136	1148	1159	1170	1181	1193	1204	1215	1226	1238	113	225	338	450	563	675	788	900	1013
44	1138	1149	1161	1172	1184	1195	1206	1218	1229	1240	1252	114	228	341	455	569	683	797	910	1024
45	1151	1163	1174	1186	1197	1209	1220	1232	1243	1255	1266	115	230	345	460	576	691	806	921	1036
46	1164	1176	1187	1199	1211	1222	1234	1245	1257	1269	1280	116	233	349	466	582	698	815	931	1048
47	1176	1188	1200	1211	1223	1235	1247	1258	1270	1282	1294	118	235	353	470	588	706	823	941	1058
48	1189	1201	1213	1225	1237	1248	1260	1272	1284	1296	1308	119	238	357	476	595	713	832	951	1070
per foot	396	400	404	408	412	416	420	424	428	432	436	40	79	119	158	198	238	277	317	356

*Use 27" for WALKING, per standard pace. For WALKING by distance, per foot, use line below.

Time for GRASP

Contact	174	176	177	179	181	183	184	186	188	190	191	17	35	52	70	87	104	122	139	157
Contact-Pinch	278	281	284	286	289	292	295	297	300	303	306	28	56	83	111	139	167	195	222	250
Pinch	357	361	364	368	371	375	378	382	386	389	393	36	71	107	143	179	214	250	286	321
Wrap	566	572	577	583	589	594	600	606	611	617	623	57	113	170	226	283	340	396	453	509

Time for POSITION

1st Degree	200	202	204	206	208	210	212	214	216	218	220	20	40	60	80	100	120	140	160	180
2nd Degree	223	225	227	230	232	234	236	239	241	243	245	22	45	67	89	112	134	156	178	201
3rd Degree	311	314	317	320	323	327	330	333	336	339	342	31	62	93	124	156	187	218	249	280
4th Degree	412	416	420	424	428	433	437	441	445	449	453	41	82	124	165	206	247	288	330	371
5th Degree	556	562	567	573	578	584	589	595	600	606	612	56	111	167	222	278	334	389	445	500

Time for ASSEMBLE

¼"**	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
⅜"	24	24	24	25	25	25	25	26	26	26	26	2	5	7	10	12	14	17	19	22
½"	89	90	91	92	93	93	94	95	96	97	98	9	18	27	36	45	53	62	71	80
⅝"	154	156	157	159	160	162	163	165	166	168	169	15	31	46	62	77	92	108	123	139
¾"	219	221	223	226	228	230	232	234	237	239	241	22	44	66	88	110	131	153	175	197
⅞"	284	287	290	293	295	298	301	304	307	310	312	28	57	85	114	142	170	199	227	256
1 "	349	352	356	359	363	366	370	373	377	380	384	35	70	105	140	175	209	244	279	314
1⅛"	414	418	422	426	431	435	439	443	447	451	455	41	83	124	166	207	248	290	331	373
1¼"	479	484	489	493	498	503	508	513	517	522	527	48	96	144	192	240	287	335	383	431
1⅜"	544	549	555	560	566	571	577	582	588	593	598	54	109	163	218	272	326	381	435	490
1½"	609	615	621	627	633	639	646	652	658	664	670	61	122	183	244	305	365	426	487	548
1⅝"	674	681	687	694	701	708	714	721	728	735	741	67	135	202	270	337	404	472	539	607
1¾"	740	747	755	762	770	777	784	792	799	807	814	74	148	222	296	370	444	518	592	666
1⅞"	805	813	821	829	837	845	853	861	869	877	886	81	161	242	322	403	483	564	644	725
2 "	870	879	887	896	905	914	922	931	940	948	957	87	174	261	348	435	522	609	696	783
2⅛"	935	944	954	963	972	982	991	1000	1010	1019	1029	94	187	281	374	468	561	655	748	842
2¼"	1000	1010	1020	1030	1040	1050	1060	1070	1080	1090	1100	100	200	300	400	500	600	700	800	900
2⅜"	1065	1076	1086	1097	1108	1118	1129	1140	1150	1161	1172	107	213	320	426	533	639	746	852	959
2½"	1130	1141	1153	1164	1175	1187	1198	1209	1220	1232	1243	113	226	339	452	565	678	791	904	1017
2⅝"	1195	1207	1219	1231	1243	1255	1267	1279	1291	1303	1315	120	239	359	478	598	717	837	956	1076
2¾"	1260	1273	1285	1298	1310	1323	1336	1348	1361	1373	1386	126	252	378	504	630	756	882	1008	1134
2⅞"	1325	1338	1352	1365	1378	1391	1405	1418	1431	1444	1458	133	265	398	530	663	795	928	1060	1193
3 "	1391	1405	1419	1433	1447	1461	1474	1488	1502	1516	1530	139	278	417	556	696	835	974	1113	1252

**¼" and less of ASSEMBLE is contained in POSITION; at least it could not be evaluated as a separate value.

Time for DISASSEMBLE

All	476	481	486	490	495	500	505	509	514	519	524	48	95	143	190	238	286	333	381	428

Time for RELEASE LOAD

All	189	191	193	195	197	198	200	202	204	206	208	19	38	57	76	95	113	132	151	170

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[1] Adapted from Lazarus, Irwin P., "A System of Predetermined Human Work Times," Ph.D. Thesis, Purdue Univ., 1952.

- d. bi-manualness involved
- e. whether the use of the feet accompanies the action
- f. the eye-hand coordination required
- g. the sensory requirements
- h. the weight or resistance involved
- i. the preceding and following therbligs as well as the context of the whole pattern of the task
- j. the direction of the movement
- k. the place of the therblig in a motion pattern
- l. the possible interactions of two variables
- m. several other variables as yet unidentified, inasmuch as even when the effects of a variable **a** through **k** are extracted, considerable variation in observed data still exists.

Several available systems of predetermined standards disregard the existence of many of these variables although this should not be thought of as a realistic procedure for eliminating these sources of error. In order to fully comprehend the method by which most of these factors are to be taken into account in the application of these data, one should have some understanding of the system of objective rating.

Objective rating consists of the following steps:

1. The rating of observed pace against an objective pace-standard, which is the same for all jobs. In this rating, no attention whatsoever is paid to job difficulty and its effect on possible pace; hence, a single pace-standard may be used instead of a multiplicity of mental concepts.
2. The use of a secondary adjustment (for job difficulty) consisting of a percentage increment, added after the application of the numerical appraisal from Step 1 has been used to adjust the original observed data. This percentage increment is to be taken from experimentally determined tables of the effect of various observable factors that control the exertion required at a given pace, and is applied element-wise, rather than therblig-wise to allow for the interaction of therbligs.

In the explanation of the procedure followed when constructing the proposed system, it was pointed out that the film of each component job was pace-rated against a single pace (the multi-image rating loop). In other words, Step 1 of the objective rating procedure had already been carried out and the resulting tables represent times which already have been related to standard.

All that remains to be done to arrive at the base time for a job is the performance of Step 2 of the objective rating procedure, the adjustment for difficulty of the job. Then the application of allowances to this base time will result in the standard allowed time for the job.

Six factors had previously been isolated for which secondary adjustments should be added and it is recommended that separate adjustments be made for each element. These six factors, along with the category breakdown of the therblig tables, take in account, to a large degree, the previously mentioned variables **a** through **i**.

The table of secondary adjustments, based on psycho-physical research appears as Table 2.

Method of Use

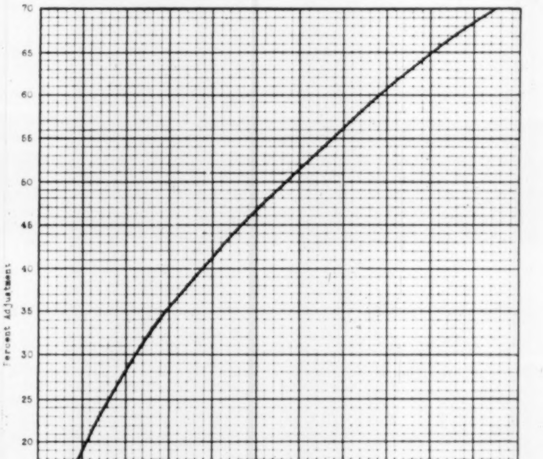
To develop a standard from the given data, the steps to be followed are:

- A. The actual or contemplated workplace or work area should be carefully dimensioned as shown in Figure 2 and the

TABLE 2[1]

SECONDARY ADJUSTMENTS FOR TIME STUDIES

Category No.	Description	Reference Letter	Condition	Per Cent Adjustment
1	Amount of body used.	A B C D E	Fingers used loosely. Wrist and fingers. Elbow, wrist, and fingers. Arm, etc. Trunk, etc.	0 1 2 5 8
2	Foot pedals.	F G	No pedals or one pedal with fulcrum under foot. Pedal or pedals with fulcrum outside of foot.	
3	Bimanualness.	H S	Hands help each other or alternate. Hands work simultaneously doing the same work on duplicate parts.	0 18
4	Eye-hand coordination.*	I J K L M	Rough work, mainly feel. Moderate vision. Constant but not close. Watchful, fairly close. Within 1/64 inch.	0 2 4 7 10
5	Handling requirements.*	N O P Q R	Can be handled roughly. Only gross control. Must be controlled, but may be squeezed. Handle carefully. Fragile.	0 1 2 3 5
6	Weight.	Identify by the letter W followed by actual weight or resistance.		Use Curve



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[1] Reprinted by permission of author, Mundel, M. E., "Motion and Time Study Principles and Practice" Prentice-Hall, Inc., New York, 1951, page 343.

*NOTE: These scales could possibly go much higher in some cases.

nature of what is to be accomplished should be summarized.

B. Using a form, such as shown in Figure 3, each element should be detailed in terms of constituent therbligs. Element of the magnitude of stop watch time study elements should be used so as to adjust for therblig interactions. The conditions of each therblig should be carefully evaluated and noted in the proper column in terms of the variables given in Table 1.

C. Using Table 2, the secondary adjustment for each element should be computed using the proper columns of Figure 3.

D. Using Table 1, the time for each therblig, for each hand, should be entered on the computation form as has been done on Figure 3, in reference to the job of Figure 2.

(It is to be noted that Table 1 gives basic times, the basic times plus one per cent increments to 1.10 of the basic time and then successive 10 per cent steps from .10 to .90 of the basic time. If the secondary adjustment is 10 per cent or less, the therblig time may be entered on a for such as Figure 3 with only one entry. If the secondary adjustment exceeds 10 per cent, two entries should be made, i.e, for a secondary adjustment of 23 per cent, both 1.03 multiple (the value from column E) and the .20 multiple (from column N) should be entered using the two time entry spaces for each therblig provided on the form of Figure 3. Unavoidable delays, holds, etc., take their value from the controlling hand. For select, basically a therblig with no controls, twice the grasp time should be used as an approximation.

E. The total element time is taken as that required by the hand with the longest or controlling time.

F. Using a form such as shown in Figure 4, the elements and job information are summarized, next the allowances (see Figure 4) and then the standard is computed. (Part of the job of Figure 2 was used again in this illustration). However, to keep Figure 3 to a single page, only two elements were treated. Figure 4, in keeping with Figure 3, treats these two elements as though they constituted the entire task.

It is to be noted, that inasmuch as the original data were developed by an objective rating procedure, which experiments have shown to be more accurate than conventional time study methods,[4] the standards that result from the use of these data should be, within limits, comparable to that resulting from direct stop watch time study using objective rating methods. This synthesizing procedure should be particularly useful for planning new work or comparing contemplated, alternative methods or as a basis for scheduling or planning production.

For most intelligent use, one should have a full understanding of the types of errors that may enter into the use of such data. Although this system accounts for the majority of the governing factors, errors may still be introduced by an improper description of the task, a wrong classification of a therblig, a poor element grouping, and the selection of incorrect secondary adjustments, as well as by the inclusion of variables (affecting the task) not compensated for in the data. This latter can most easily occur in the handling of non-mechanical or peculiarly delicate materials, or complex motions.

Results from Use of the System

As has been previously mentioned, employees of 52 separate Ordnance installations have already been trained in the use of this system. Their results have shown the system to be accomplishing desirable work measurement objectives. One Pennsylvania installation, employing ten thousand people, reports an average error of 3.9 per cent for this system when compared to compatible stop watch time study. (The per cent error was computed by finding the difference in time between each synthesized standard and the time study standard, dividing by the time study standard and multiplying by 100). This installation recently completed the training of 22 new engineers in the use of this system. A New Jersey installation, employing 7,500 people reported an average per cent error of 8.4 when compared to time study. This installation had performed a check study by applying a presently sold civilian system (by a man trained in the use of that systhem) to synthesize the standard time for a series of 24 operations. The standards were also determined using the Ordnance Predetermined Approximate Performance Times. The average error between time study and the civilian system was 8.5 per cent. The average error between time study and the Ordnance system was 6.2 per cent. On the basis of such personally made studies, Ordnance installations are refusing to let costly contracts to private consulting firms for the setting-up of pre-determined time standards system.

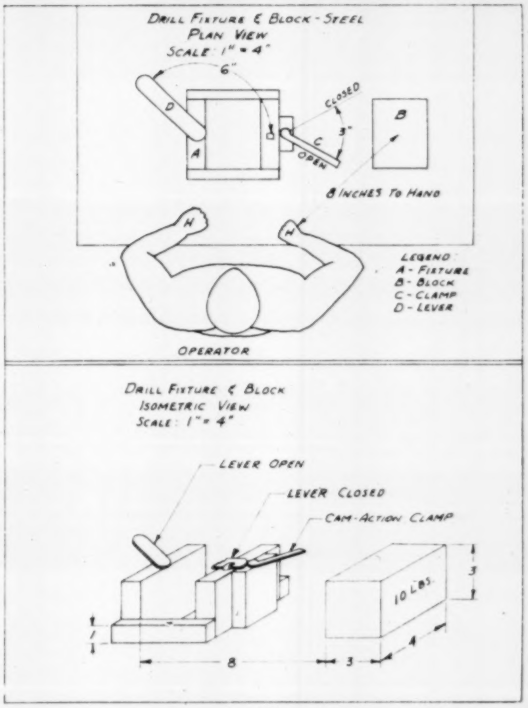
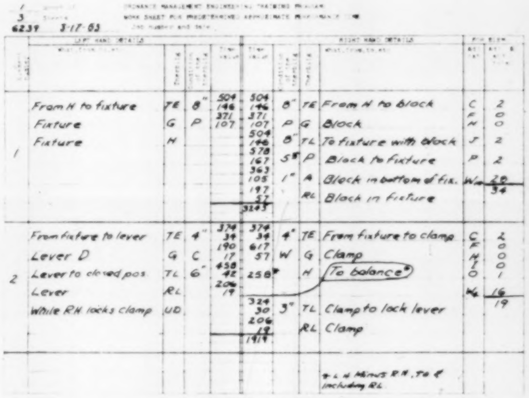


Figure 2.



1
3
6239 3-17-53

ORDNANCE MANAGEMENT ENGINEERING TRAINING PROGRAM
WORK SHEET FOR PREDETERMINED APPROXIMATE PERFORMANCE TIME
Job number and date

1	From H to fixture	TE	8"	504 146	504 146	8"	TE	From H to block	C	2
	Fixture	G	P	371 107	371 107	P	G	Block	F H	0 0
	Fixture	H			504 146	8"	TL	To fixture with block	J	2
					578 167	5*	P	Block to fixture	P	2
					363 105	1"	A	Block in bottom of fix.	W	28 34
					197 57		RL	Block in fixture		
					3243					
2	From fixture to lever	TE	4"	374 34	374 34	4"	TE	From fixture to clamp	C	2
	Lever D	G	C	190 17	617 57	W	G	Clamp	F H	0 0
	Lever to closed pos	TL	6"	458 42	258*		H	To balance*	I O	0 1
	Lever	RL		206 19					W	16 19
	While RH locks clamp	UD			324 30	3"	TL	Clamp to lock lever		
					206 19		RL	Clamp		
					1919					
								* L H Minus R.H. TE & including RL		

Figure 3.

A Nebraska installation reports that this system has helped immeasurably in the job of balancing ammunition rebuild lines. Another says it saves time in estimating costs for packing and depot operations. Thus far, the reporting installations have stated the following as advantages of this system over stop watch time study:

1. Serves as an estimator or predictor before job is run for the purpose of:
    a. Scheduling product flow thru the process sequence.
    b. Estimating labor and machine cost on new work (for predetermining personnel needs and budget or production requirements).
    c. Balancing operation times in assembly line work.
    d. Comparing alternative job methods undergoing selection.
    e. Securing a reasonable approximation of the correct time to perform a difficult task when only unskilled, untrained operators are available to perform that task
2. Eliminates the job of rating, although judgment is still required in entering the tables. However, wild errors seem to be eliminated.
3. Quicker to apply (cheaper).
4. Easier to use (less skilled people can use it).
5. Makes time study men methods conscious.
6. Acts as an aid in Methods Study (the quicker motions being the better to select) and is compatible with the usual methods analysis.
7. Aids in determining whether neophyte time study men are producing reasonable standards.

The Ordnance Predetermined Approximate Performance Times have already proved a useful tool to our management people. Their ease of use has brought quick popularity. However, their very name forces us to remember that they are only an approximation of that nebulous concept, correct standard allowed job time. Should one desire closer results

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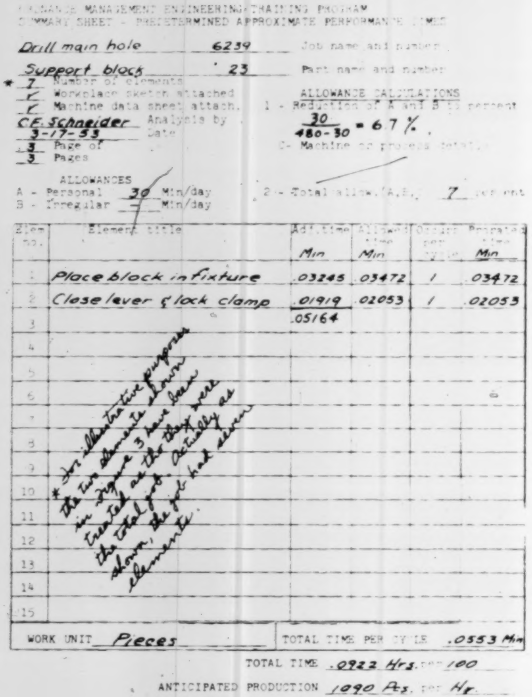
[4] Mundel, M. E., Motion & Time Study Principles and Practice, New York, Prentice-Hall, Inc., 1950, p 322.



ORDNANCE MANAGEMENT ENGINEERING TRAINING PROGRAM
SUMMARY SHEET - PREDETERMINED APPROXIMATE PERFORMANCE TIMES

Drill main hole 6239 Job name and number
Support block 23 Part name and number
* 7 Number of elements
✓ Workplace sketch attached
✓ Machine data sheet attach.
C.E. Schneider Analysis by
3-17-53 Date
3 Page of
3 Pages

ALLOWANCES
A - Personal 30 Min/day
B - Irregular — Min/day

ALLOWANCE CALCULATIONS
1 - Reduction of A and B to percent
$\frac{30}{480-30} = 6.7\%$
C- Machine or process detail
2 - Total allow. (A, B,) 7 per cent

Elem no.	Element title	Adj. time Min	Allowed time Min	Occurr per cycle	Prorated time Min
1	Place block in fixture	.03245	.03472	1	.03472
2	Close lever & lock clamp	.01919	.02053	1	.02053
3		.05164			
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

WORK UNIT Pieces
TOTAL TIME PER CYCLE .0553 Min
TOTAL TIME .0922 Hrs. per 100
ANTICIPATED PRODUCTION 1090 Pcs. per Hr.

* For illustrative purposes the two elements shown in Figure 3 have been treated as tho they were the total job. Actually as shown, the job had seven elements.

Figure 4.

than the 5 to 10 per cent deviation from time study that this system produces, he should turn to repeated time studies to solve this problem. These predetermined times are simply an additional tool available to progressive management that should not be thought of as replacing other available techniques. We believe their use will aid in producing more consistent standards in the sprawling industrial complex that is the Army Ordnance Corps.

THE MEDIA OF MANAGEMENT CONTROL

(Continued from Page 9)

ence in the event the new component was incorporated in a future design. Likewise, the manufacturing department looked to the new department to relieve it of responsibilities which heretofore it had refused to recognize it could not satisfactorily fulfill. Manufacturing consulted the new department not only as to difficulties encountered in executing the plans delivered to it, but in ways and means of improving operating efficiency and productive capacity. Much to our surprise, we found the relationship between the Industrial Engineer and the line organization reversed. It behooved the members of the new department to remember well their experiences before this situation was reversed, and give full consideration to all proposals emanating from the manufacturing organization. In this atmosphere our progress in efficiency development far surpassed our optimistic expectations.

The new department was in need of a title, and for expeditious reasons it was called the Cost Control Department.

The Cost Control Department developed the detailed plan of operation and then predetermined costs. Such costs were submitted to management as reliable data for the determination of sales and selling prices, and once top management approved the plan and established a date for its execution, every member of the organization concerned with operations received specific instructions in the execution of his portion of the plan. In this manner we successfully resolved "how to get everyone in accord on the detailed methods to be employed in manufacturing." The Cost Control Department had its own means of policing operations. The time-study section established time standards and production rates,, which, of course, were based upon planning in which it had an active part. Where manufacturing was having difficulty in meeting the rates, the time-study engineer promptly followed through to determine if operations were being conducted in accordance with plan.

We have covered a complex subject in a short period of time and consequently it has been necessary to omit many details. I have endeavored, however, to provoke thinking on the part of both management and the Industrial Engineer as to ways and means of obtaining the full potential benefits from the Industrial Engineering department.

PRESIDENT'S MESSAGE

(Continued from Page 2)

"selling" would not have to be so belabored.

You have to admit that this is a provocative observation and one that highlights the role of the Industrial Engineer to create change in our dynamic world. While a great deal can be said pro and con to the above, I would like to develop what I feel is the germ of a constructive thought that can be extracted from the incident.

It is generally recognized that the appropriate function of the Industrial Engineer consists of the necessary research, the designing, testing, and installing of new methods, procedures, processes, organizations, etc., and that a successful solution is a part of the job. The "selling," as it is often called, occurs during the installation phase where the proposed solution must be o.k.ed by management (directly, or by delegation) and also accepted by those who must perform in the new manner or method. Now, if the design is inadequate, an inordinate amount of "selling" the supervisory group and the workers will be required. Then, if this system (or method, etc.) is to be perpetuated, a *continuous* job of convincing or "selling" will be required.

Perhaps this leads to a clue in evaluating the real efficacy of our Industrial Engineering in a given plant. If it is found that a tremendous amount of the Industrial Engineering effort is being spent in the installation phase and that the planning and design of new systems and research into new techniques is given relatively little attention, perhaps, in effect, an alarm is sounded. Perhaps an indication such as this is the only symptom of an unhealthy design that we shall receive.

Thus, it would appear that the content of the work load in Industrial Engineering should be carefully and periodically examined. While from time to time greater emphasis will be needed on one or another of the phases, in the long run some balance should exist. The installation phase, if it is a sore spot that requires continual fire fighting, may be compared to an inadequate machine that must be held together with baling wire in order to meet the performance load required. What *may* be needed is a new design!

This is where the true mettle of the engineer is brought to bear—to design a new system and convince management that it *is* needed when the present one can be *made* to work. This may be an appropriate time to ask whether we are doing enough research into the nature of this installation phase. Have we adequately determined generalized principles that can be used in the design of the installation procedure and schedule?

Since the last issue of the JOURNAL, three additional chapters have been issued charters. Welcome is extended to the members and officers of the Peninsula (San Mateo, California), the Twin Cities (Minneapolis-St. Paul), and the San Antonio Chapters. Past-President Matt Payne is doing a wonderful job as Director of Chapter Extension.

JOB HUNTING MADE EASY

(Continued from Page 11)

ings of direct labor personnel. If we accomplish this, we then would save an additional 9 persons for a total of $36,000 a year.

Old Work Force =	**153**
Save =	**9**
New Work Force =	**144**
Yearly Savings = $	**36,000**
Total Savings = $3,424,000	

Gentlemen, I could go on but I think this is a good plan for a starter. I think that the savings we have now enumerated which now total $3,424,000 in this 12 step plan should prove attractive enough to you. Your work force has been reduced from 1,000 to 153. There are yet unenumerated savings totaling hundreds of thousands of dollars in fringe benefits (vacation costs, Social Security, etc.).

In about a year, when all of these plans have been accomplished, I think I can do the same thing again, when we study the effects of the nervous requirements of the jobs, the impact of medical exams, the worth of a training program, the installation of a first class safety program. We might add a study of employee housing, employee counseling and suggestion plans, athletics, as well as the worth and value of company picnics. I'm certain that we can provide you facts and figures on each of these things that will set up a program just as attractive as the one we have just mentioned.

There, gentlemen, are my thoughts. When do we start work?"[4]

D. H. DENHOLM
Chief Industrial Engineer
Chase Bag Company

IE AND OR—A CRITIQUE

(Continued from Page 12)

by work measurement and incentive concepts. In fairness to industrial engineers it must be said that they too have broadened their vision, but, still, operations research literally compels consideration of many facets of action problems which traditionally have not been studied by industrial engineers."

The writer feels that I. E. and O. R. have the same goals but, based on the reported case histories of both, the difference in the fields is twofold:

1. O. R. aims to apply itself to any and all phases of business activity whereas I. E. has been, in general, much more limited. The writer cannot help feeling, however, that some of the cited examples of O. R. are just broad management studies that have been renamed Operations Research. This is particularly so when the study was made without mathematical tools, as is mentioned below.
2. According to the literature, O. R. intends to employ mathematical and statistical techniques to a much greater degree than I. E. However, [3]"a majority of O. R. problems have been solved and most useful results obtained without going much beyond the concepts of simple arithmetic." Some British O. R. people wish to de-emphasize the role of mathematics in the solution of O. R. problems. If this is done, then only the type of problem could differentiate O. R. from I. E.

The problem is further aggravated today because the O. R. field is composed almost entirely of pure scientists. Their ignorance of management principles has placed them in the same position as early Industrial Engineers. At a recent panel on Operations Research, a statistician of national prominence described his experiences in O. R. with the Navy. The O. R. group received a problem and proceeded to decide what data would be necessary for a solution. Unfortunately, the group had no idea that there was a selling phase to their job so they simply strolled into the operating departments and asked for the data. The operating departments responded with a 6 gun salvo. The group was amazed at the total lack of cooperation from the operating departments. Of course, they finally realized the necessity that the departments be convinced of the need and the usefulness of the O. R. group. After this had been done, the group obtained the necessary data. This is old hat to the Industrial Engineer but I wish you could have heard the amazement in the voice of the statistician as he described this experience.

Some people believe that the "management aspects" of a problem simply mean the "selling phase." In describing the industrial applications of O. R., a consultant mentioned the following: "One organization reported the formation of groups composed of representatives from research, production, and sales divisions to study manufacturing operations and recommend improvements." One would hope that the principle of coordination be recognized as a principle and employed on every management problem instead of regarded as an incidental tool employed at one company. Some leaders have recognized this weakness in O. R. and have added management people to the teams. This is certainly commendable but the writer personally feels that the team should always be *headed* by a management man.

Summing up, the emergence of a field of O. R. is partly due to the narrow practice of Industrial Engineering and the failure of Industrial Engineers to make more use of mathematical techniques. There is definitely a large overlap between O. R. and Industrial Engineering. To those who feel that O. R. should be regarded merely as a mathematical tool of Industrial Engineering, a prediction from the Harvard student report accurately reflects the enthusiasm of practicing O. R. people: "The recognition of O. R. as a new science is unavoidable. 'Operations' will become a concept like 'electricity'."[3]

Industrial Engineering is still struggling for recognition as a profession. The similarity between Operations Research and Industrial Engineering is going to confuse the issue. What are we going to do about it? It seems to me that a good start would be to settle on a definition of Industrial Engineering. I personally hope that the definition is broad enough to cover the many new facets of Industrial Engineering work. It's time we let it be known that we are a dynamic profession capable of applying the engineering approach to all types of problems of an industrial society.

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[3] Gerhard R. Andlinger *et al.*, *Operations Research Challenge to Modern Management*, Cambridge, Mass., printed privately, 1954.

[4] Robert H. Roy, "Operations Research and Industrial Engineering: Contract and Resemblance," *The Scientific Monthly*, September 1953, pp. 163-164.

THE NEW LOOK

(Continued from Page 4)

is best explained by an example. Let us say an Industrial Engineer has a problem. He will try to solve it with the set of techniques which is peculiar to Industrial Engineering. When he has exhausted the use of these techniques in trying unsuccessfully to solve the problem, the Operations Research analyst becomes interested and solves it using his more powerful Operations Research techniques. That, then, illustrates the difference between Operations Research and Industrial Engineering." Paraphrased he said "an Industrial Engineer is an engineer that did not graduate from college." For indeed, the universally accepted definition of engineering does not restrict it to any particular subset of scientific techniques or principles. Engineering properly conceived and practiced already spans the full range of relevant scientific principles and techniques. It is already the responsibility of the engineer working with any given problem to bring to bear any available scientific principle, method, or technique which may be necessary to solve that problem. In some cases he may have to develop new concepts and methods. Now, an Industrial Engineer is first an *engineer* and secondly an engineer working on *industrial* problems, just as a doctor of medicine is first a physician and secondly a specialist, say, a urologist. Hence, we can not accept the assertion that "Operations Research" is the exclusive owner or user of any technique or set of techniques necessary to the solution of an engineering problem; if any individual has no training in the necessary scientific techniques beyond the operator chart and the flow chart, he does not deserve to be called an Industrial Engineer.[3]

The large breadth of the subjects which have been claimed as "operations research" is illustrated, for example, by Johnson (2), p. 103, where he cites as an example of Operations Research a strictly product design engineering problem solved by the use of symbolic logic. Now, how ambitious can Operations Research become? Boolean algebra or logic is used regularly by many engineers; it is a most important tool for example in circuit and switching analysis, used long before the name Operations Research was even conceived. It is but one of many mathematical techniques that all engineers use. Because an engineer uses mathematics, statistics, or other tools does not change his work from engineering to Operations Research.

However, the deepest concern to us all is that the American Society of Mechanical Engineers effectively acknowledged that its own Management Division has failed to develop this field of engineering properly by publishing an unrebutted article by Morse (3) wherein several ordinary engineering problems in production scheduling, inventory control, etc., originally propounded by Taylor, are called "Operations Research" instead of "engineering" problems simply because he (Morse) introduces a little mathematical method and notation. It is a dismal commentary to note that the American Society of Mechanical Engineers is the engineering society before which Taylor presented his original papers. Now 50 years later, it still has so failed to develop the engineering methods of the field properly that it describes as "Operations Research" some of the very same engineering problems that Taylor originally discussed. It is as if applied mechanics, electronics, or other branches of engineering no longer would be considered engineering because it uses mathematical or logical analysis.

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[3] One legitimately may ask "why worry about what name is applied to this area of intellectual activity?" The answer to this question is, indeed, much of the basis for my position against the name of "operations research" and in favor of a name which is more descriptive and which includes either "engineering" or "management." For example, if it is "industrial engineering," the subject matter then is one which almost of necessity must **now** be regularly included in all of the many IE curricula or as soon as the IE faculties are tooled up to teach it. The same can be said with respect to what must be done if the team is, say, "Management Sciences." The business schools then should have to review their curricula and consider if they wish to train these scientists of management. However, if it is termed operations research, these groups may take the attitude that "this is not our subject matter and, hence, of no concern to us." If this should happen, there surely will be a further unfortunate delay in the inevitable extension of these methods into IE or BA curricula—a serious loss to society and to the profession because there is now only one formal OR curriculum in the nation, but many excellent IE curricula teaching the same material but under the name of IE. A review of IE curriculum accreditation requirements now may well be appropriate.

But there are other serious implications. Rinehart, past president of Operations Research Society of America, (4) in his retiring presidential address speaks of "threats to the growth of Operations Research," and of the need for *licensing and registration of Operations Research analysts*. Should this occur, it would effectively legislate Industrial Engineering as a bona fide branch of engineering out of existence. He also spoke of protecting the "good name of Operations Research," by making restricted membership in Operations Research Society of America endorsement of professional competence in this field. Of course, Operations Research Society of America already has a complete paraphernalia of self-appointed and self-perpetuating fellows to govern the associate members. Hence, both the legal and professional avenues to the proper practice of Industrial Engineering could be closed to trained Industrial Engineers.

In the face of all this arising confusion, one wonders how Physicist Morse (or Chemist Kimball) would react to a group of engineers who, upon developing a new branch of physics, should proclaim "Here is a new science we call 'nuclear research.' We have fissionable molecules, so no longer do we call this science physics. All physicists are forthwith out-of-style, out-of-date, and incompetent unless we vote them otherwise. Whenever anyone uses the theory of relativity, he is a Nuclear Researcher; when he uses Newtons' old laws of motion he is a physicist." This is an exact analogy of what he and his associates are saying of many fields of engineering by making their enormous claims of all that Operations Research[4] alone can do and what it includes.

Indeed, the Industrial Engineer now must give his field a "new look," define his objectives in the light of his enlarging job, and prepare to meet the coming challenges. For, surely as a man is measured by the problems with which he is confronted, so also will our profession be measured. Whether that measure be reduced to time study and quality control or expanded truly to Industrial *Engineering* lies collectively in our hands.

However, I have yet to find any paper on "Operations Research" that could not correctly be described as a subject of one of the traditional disciplines, such as economics, management, mathematics, or engineering. While I encourage more work of this type, I regret that our colleagues have confused so many issues and ideas and increased the splintering and the fragmentation of scientific knowledge into more sealed compartments.

It should be noted that I welcome these scientists into our field — we can use their help. I regret only their use of the term "operations research." They, like Alice-in-Wonderland, may use words to mean what they chose, but we are not obliged to accept their usage; indeed, I recommend we do not.

If any criticism is implied in my remarks, it is directed not toward these scientists, but toward ourselves in Industrial Engineering. In particular, it would be toward Industrial Engineers since Taylor who failed to develop necessary analytic procedures. For example, in biology, when those scientists had, say, to compare means of the experimental results of two alternative processes, they proceeded to develop or greatly aided in developing the necessary fields of statistics. (This same kind of thing also occurred in many other fields, such as psychology in relation to factorial analysis, etc.). But, for comparing means in Industrial Engineering, the early Industrial Engineers developed only the "before-and-after motion picture," operator charts, etc. While these may be interesting, they are not engineering. Hence, from an analytic point of view, we now have to make up for a generation of lost time in order to bring our field up to its proper level.

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[4] I avoid completely (a) criticizing the excellent engineering and applied mathematics work of many people who call themselves operations research analysts or (b) making any definition of operations research.

(1) Laderman, J. et al, "The Inventory Problem," *Journal of the American Statistical Association*, Vol. 45, No. 264, December 1953.

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